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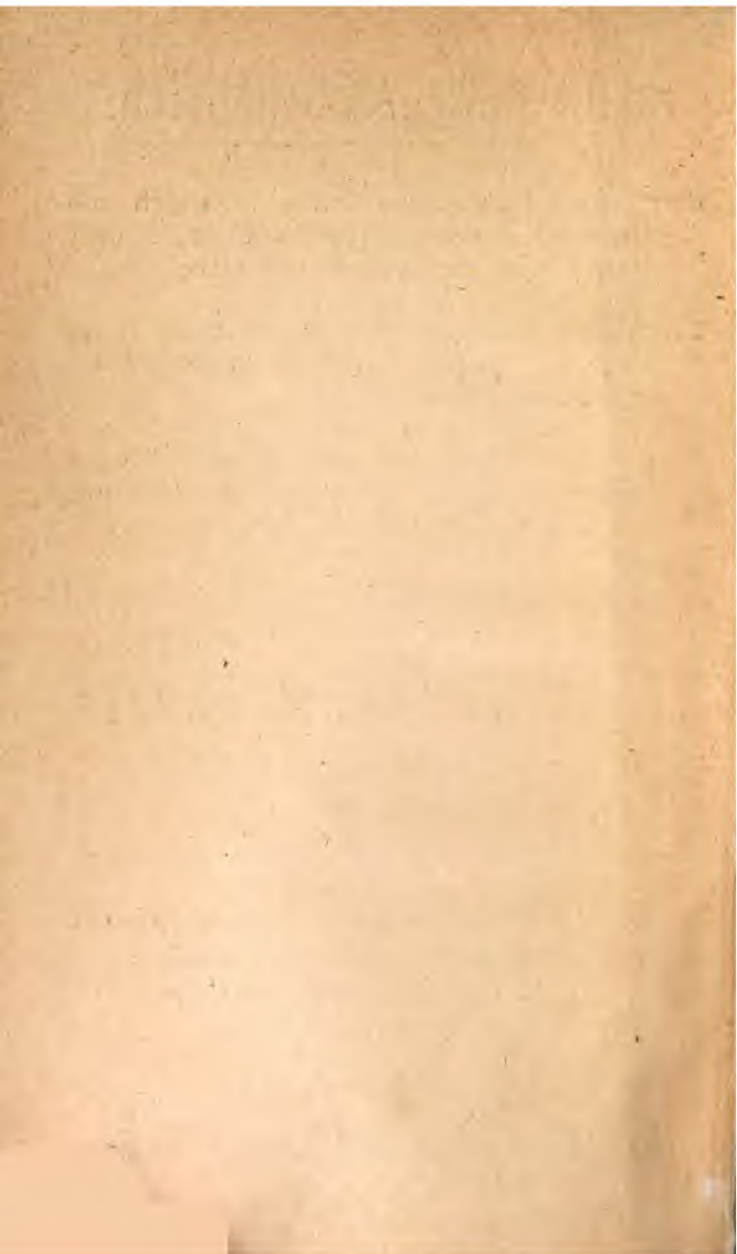
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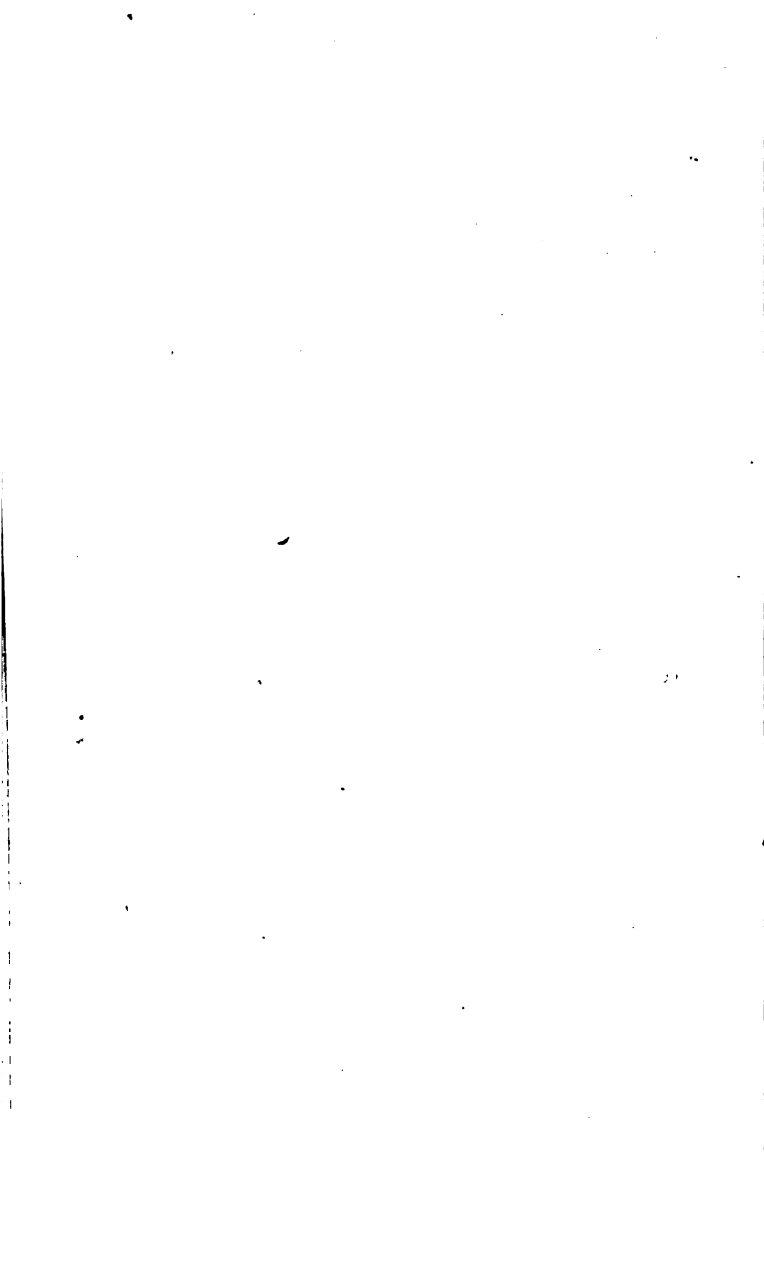
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— THE —

AMERICAN GAS ENGINEER

AND

Superintendents' Hand Book,

CONSISTING OF

RULES, REFERENCE TABLES

And Original Matter Pertaining to the

MANUFACTURE, MANIPULATION ^{AND} DISTRIBUTION

OF

ILLUMINATING GAS,

BY

WILLIAM MOONEY.

NEW YORK:
PUBLISHED BY THE AUTHOR.
1888.

T4753

71

TO THE
OFFICERS AND MEMBERS
OF
THE SOCIETY OF GAS-LIGHTING,
BY THE AUTHOR.

*S. F. &
Henry East Miller*

THIS BOOK IS RESPECTFULLY DEDICATED
TO THE
OFFICERS AND MEMBERS
OF
THE SOCIETY OF GAS-LIGHTING,
BY THE AUTHOR.

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WILLIAM MOONEY.

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PREFACE.

A FRIEND of the author, to whom the publication of this work was mentioned, took occasion to say that such a book "would fill a void of long standing." It remains to be seen whether this was an outbreak of prophetic wisdom, or a mere expression of freindship.

If this book should fail to fill the said "void" it will be at least an attempt in that direction, which may be fully accomplished in a future edition.

There is no good reason why there should not be an American Hand Book for gas engineers and others engaged or interested in the manufacture of gas. Our coinage, weights and measures are different from those of other countries, and we differ greatly in many other things. Even our English relatives, speaking the same language, have a different coinage, and many differences in their weights and measures.

Much valuable matter, the fruit of experiments and study by men eminent in the profession, is practically lost, when published in the technical journals, and when wanted, cannot readily be found.

In this work, such matter has been collected, classified and arranged so that it can be easily found.

So rapid is the march of improvement in the science of gas-making and kindred industries, that no work can keep up with it. Under the spur of active competition and the introduction of lighting by electricity, improvement in the manufacture, distribution and use of gas have increased rapidly, and no doubt every succeeding year will witness the same, or still greater activity.

Believing that the subject of chemistry is receiving more attention than formerly from gas engineers and others engaged in the business of supplying artificial light, much more space has been given to that subject than is usual in books of reference.

A work of this kind, must of necessity be made up in a great measure, of the writings of others; there is, however, a little original matter mixed in to cement the elements together.

The author is greatly indebted to Mr. Wm. Farmer, with whom he has been associated in business for many years, for much original and valuable matter, and also to the members of the Society of Gas-Lighting, for their experience, &c., as found in the publications of that society.

The chemical symbols used in the "Epitome of Chemistry" are the invention of Mr. Farmer, who has kindly consented to their use in the work.

Much material has been taken from the works of Hartley, Wanklyn, Newbigging, Steele, Box and many others, and also from the various Gas Journals.

Sincerely thanking the Gas Fraternity for their (prospective) patronage, I remain,

Yours, very truly,

WILLIAM MOONEY.

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THE RELATIVE VALUES OF GAS COALS AND CANNELS.

The following particulars embrace the principal items and products, whose values affect and determine the relative values of different qualities of gas coals and cannel.

These are :—

A.—The amount of gas—per ton—this particular sample of coal or cannel will produce

B.—The illuminating power of the gas produced.

C.—The weight of red hot unslaked coke a ton of coal or cannel will produce, the percentage of ash this coke contains, together with the evaporative power of this coke, ascertained in furnaces so constructed as to be suitable for determining this value.

D.—The weight in pounds and the strength of the ammoniacal liquor produced from one ton of material, stated in terms of Twaddell's hydrometer, together with the weight of carbonic acid, and sulphuretted hydrogen present in the production of liquor from a ton of the coal or cannel.

E.—The weight of tar in pounds a ton of coal or cannel produces.

F.—The volume or weight of carbonic oxide present in the gas.

G.—The carbonic acid present in the whole of the *crude* gas produced from a ton of coal or cannel.

H.—The sulphur compounds, sulphuretted hydrogen, and bi or di sulphide of carbon present in the gas a ton of coal or cannel produces.

In estimating and allowing for the cost of removing the carbonic acid, sulphuretted hydrogen, and bi-sulphide of carbon, which remain after a portion of these impurities have been removed while the crude gas was in contact with the ammoniacal liquor, the better way seems to be to ascertain the number of pounds, and the fraction of a pound of hydrate of lime requisite to purify 1000 cubic feet of gas.

—GRAHAM.

COALS FOR GAS MAKING.

A knowledge of the character and quality of Gas Coals is a most important part of the education of the Gas Engineer and Manager. This knowledge to be of use must, for the most part be learned from actual practice, by the use and analysis of the coals. The points to be determined as to the quality of coals, are the yield and quality of the gas, and coke and the amount of sulphur, and ash contained in them. The following observations on "Gas Coals" are condensed from "The Lithology of Gas Coals" by Mr. James Patterson.

There are certain indications more or less defined which justify at least the presumption whether the coal is suitable for gas making purposes or otherwise. The first of these is *cubical structure*. It occurs, stratified, massive, columnar and in ovoidal concretions. Our supply of gas coal is derived almost wholly from the two first classes, they are generally divided into parallel layers of various thickness. Vertical to these parallel lines the layers are divided by calcareous formations which are not objectionable in a good gas coal.

"*Lustre*" All gas coals possess a degree of lustre more or less bright, but there are coals with a bright lustre, altogether unsuited for the purpose of gas making—and experience can alone identify this difference.

"*Fracture*" These are distinguishing marks of a good gas coal. When gently broken they will show the fractures to be either cubical, conchoidal, or angular—presenting a fine pitch like surface. When the surface is scratched with a nail or a steel point, and the eroded surface shows a dull brown, or a brown inclining to black, it is an indication of a coal rich in hydrocarbons. Rubbing two surfaces together, and exposing the abraded surfaces to the light, when the depth of the brown shade will be better indicated is also a good test. This is the most reliable of all the external evidences of a good gas coal or cannel. The coking qualities of a coal may be readily indicated by its combustion on the fire.

"*Sulphur*" The amount of sulphur in combination with coal for the purpose of gas manufacture is a matter of great importance as an excess of that impurity requires additional purifying surface and materials. The distribution of this impurity throughout a mass of coal is so arbitrary and capricious, that in the

majority of cases, a quantitative analysis cannot be relied upon. The only reliable test is the amount of shell lime required to purify a given amount of gas.

Bituminous coal deteriorates considerably as a gas-producing agent by being stored for any length of time, especially if exposed to the sun and rain.

COMPOSITION OF CAKING COALS.

Carbon.....	81.81
Hydrogen.....	6.00
Nitrogen.....	1.28
Sulphur.....	1.69
Oxygen.....	2.58
Ash.....	6.64

100.00

One ton of Caking Coal, properly carbonized will produce—
11,200 cubic feet of 16 candle gas, weighing.....375.00 lbs

Weight of Tar.....	101.00	"
" " Liquor.....	110.00	"
Impurities SH_2	7.00	"
" CO_2	31.00	"
Ammonia ..	2.50	"

626.50 "

And Coke.....	1560.00	"
Leaving a loss of.....	53.50	"

Total weight.....2,240.00 "

EXPOSURE OF COAL.

According to experiments made in Germany, coal exposed to the weather in heaps, lost during a period of nine months 50 per cent. of its value as fuel, and about as much as a gas making material; it undergoes a process of slow combustion taking up oxygen, and giving off the volatile products of oxidation, air and moisture playing the principal part, and warmth promoting it. The valuable combustible ingredients are lost, and the injurious ones, as sulphur, and ash are relatively increased. Coke from coal that has been exposed to the weather, is of inferior quality—losing its coherence.

Coal exposed to the weather should be provided with pipes of sufficient diameter to allow the passage of a thermometer, which should be lowered to the bottom daily. The pipes should be lettered, and a record kept of the temperatures, which should be carefully watched as they approach 200° F. For some reason not explained, the temperature will often reach nearly a firing point, and then recede from it. The points most liable to spontaneous combustion, are those nearest to any timbers extending down to the bottom of the heaps.

ANALYSIS OF AMERICAN GAS COALS.

Name of Mine, Coal or Company.	Yield per Ton.	Yield per lb.	Can- dle Power	Can- dle Feet.	Where or by whom tested
Montauk Taylor Co	11693	5.22	16.11	84.00	Prof. Rickets and Sloan.
Straughn.....	12300	5.49	14.97	88.44	
Utopia.....	12960	5.78	15.96	92.24	
Blacksburg.....	13020	5.72	16.75	95.81	
Coal Valley.....	11520	5.14	16.00	82.24	
Upper Creek.....	12340	5.50	16.37	90.03	Wallace of Glasgow. Phila. gas works.
Cannelton Cannel..	12510	5.58	36.55	203.94	
Monongahela.....	11648	5.20	15.00	78.00	
Murphy Run.....	11390	5.08	18.95	96.26	
Penn.....	12067	5.38	15.05	80.96	
Youghiogheny....	12215	5.45	14.47	78.86	Manhattan gas works Nassau " "
Old Virginia.....	10414	4.64	13.28	61.62	
Blacksburg.....	11787	5.26	15.12	79.53	
Westmoreland....	11883	5.30	14.19	75.20	
Taylor County....	12563	5.60	16.33	91.44	
" "	11066	4.93	18.01	88.79	Phila gas works. Nassau " "
Youghiogheny....	11621	5.14	15.61	80.23	
Cannelton Cannel..	12000	5.31	37.00	196.47	
Breckenbridge "	13938	6.22	55.25	343.65	" " "

FROM F. S. BENSON,
Nassau Gas Co.

KANAWHA COALS.

These coals are mined in the Great Kanawha Coal Region—and are shipped principally from points near Cannelton by the Chesapeake and Ohio Railway.

Analysis of Kanawha Gas Coal, and Cannelton Cannel, by Prof. Rickets of the School of Mines, Columbia College, N. Y., are as follows:—

KANAWHA GAS COALS.

Volatile Matter.....	37.36
Fixed Carbon.....	56.26
Ash.....	3.85
Sulphur.....	1.28
Moisture.....	1.25

Total.....100.00

Specific Gravity, 1.262. Weight per cubic foot 78.74 lbs
 Standard Yield, 12000 Cubic feet per ton, candle power 18.
 Bushels of Coke, 34. Pounds of Coke 1518.

CANNELLTON CANNEL.

Volatile Matter.....	58.00
Fixed Carbon.....	23.50
Ash.....	18.50

Total.....100.00

Yield of Gas per 2240 lbs, 12025 Cubic feet of 45.60 Candles
 Coke. 32 Bushels, quite light, burns freely, making very hot
 fire.

Sulphur. 5238 Cubic feet Gas purified by one bushel of
 Hydrate of Lime.

The following tests of Kanawha Coal were made by Mr. C.
 J. R. Humphreys, for the purpose of comparing the values of
 Slack and Lump Coals.

FIRST TEST—974 lbs. of fine coal—Bench of 5 Retorts. Gas
 made per ton of coal 10 243 ft., Candle power 17.1; = 78.1 Candle
 feet Coke per ton of coal, 1516 lbs. weighed hot, bushels of
 Coke per ton, 46 Coke, large, and not thoroughly burned—
 yielded on screening $1\frac{1}{2}$ bushels breeze = 3.4 bushels per ton of
 coal. Duration of charge 4 hours, heats not regular.

SECOND TEST—965 lbs. lump coal; conditions same as before,
 but heats not so high.

Gas made per ton of coal 10.312 cubic feet. Candle power
 18; = 82.8 Candle feet. Coke made 1.538 pounds per ton of
 coal, weighed hot, bushels of coke per ton of coal 42. Coke small,
 grayish in color, and quite hard. On screening gave 2.7 bushels
 of breeze per ton of coal.

The yield of gas in both cases, was corrected to 60° Fahr.

The results of the tests were as follows :—

The lump coal gave 70 feet more of gas per ton, with a gain of nearly one candle power in quality.

The coke from the fine coal was larger, much more friable, and would readily fall into breeze; like all coke not fully carbonized it would not burn well, and was inclined to smoke.

The fine coal would certainly require much more fuel for carbonization than the lump.

The experiments confirmed the general belief as to the comparative value of slack and lump coal.

WEST VIRGINIA COALS.

The quality of coal known in the New York and Eastern markets as "West Virginia Gas Coal" is mined in Taylor, Harrison, and Preston Counties, West Va., the mines being located, near to or upon the main line of the Baltimore and Ohio Railway. The principal mines are those of the Despard, Newburg Orrel, Tryconnel, Fairmount, Consolidated, Monongahela, and Gaston Coal Co.

Analysis of the Gaston mine coal by S. Calvert Ford shows :

Volatile Matter.....	39.60
Fixed Carbon....	54.92
Sulphur.....	.89
Ash.....	4.59

100.00

Practical result shows 5.44 cubic ft. per lb. of coal or 12185 cubic ft. per ton of 2240 lbs.

Analysis of Clarksburg, West Va., Coal shows :

	Vol. Matter.	Fixed Carbon.	Ash.
Clarksburg, main seam....	56.74	41.66	1.60
Clarksburg Cannel.....	49.21	45.43	5.36

MIXTURES OF COAL AND CANNEL.

Name of Coal and per centage used.	Yield per lb. Cub. feet.	Yield per Ton. Cub. feet.	Cand- dle Power	Cand- dle feet.
Cannelton Cannel 10 per cent. and Youghiogheny Coal 90 per cent.....	5.19	11626	17.01	88.28
Bog Head Cannel 10 per cent. and Youghiogheny coal 90 per cent.....	4.86	10886	18.81	91.42
Bog Head Cannel 10 per cent., You- ghiogheny coal 60 per cent. and Murphy Run coal 30 per cent.....	5.13	11491	17.80	91.31
Cannelton Cannel 10.23 per cent. Youghiogheny Coal 62.26 per cent., and Montauk coal 27.51 per cent.....	5.11	11446	17.31	88.45
Cannelton Cannel 9.09 per cent. You- ghiogheny coal 30.30 per cent. Montauk Coal 30.30 per cent., and Powelton Coal 30.31 per cent.....	5.25	11760	17.50	91.88
Bog Head Cannel 10 per cent. You- ghiogheny coal 40 per cent. Penn. nut coal 20 per cent., and Gaston Coal 30 per cent.....	5.21	11670	17.47	91.02
Bog Head Cannel 9.93 per cent. You- ghiogheny coal 21.26 per cent., and West Fairmount coal 28.81 per cent....	5.16	11558	17.61	90.87
Bog Head Cannel 10 per cent. You- ghiogheny coal 30 per cent. Montauk coal 30 per cent., and Powelton coal 30 per cent....	5.28	11827	17.65	93.19
Bog Head Cannel 9.08 per cent. You- ghiogheny coal 64.63 per cent., and Gas- ton coal 26.29 per cent.....	5.23	11715	17.32	91.62
Bog Head Cannel 9.05 per cent. You- ghiogheny coal 27.07 per cent., and Powelton coal 63.88 per cent.....	5.27	11805	17.36	91.49
Bog Head Cannel 10.26 per cent. You- ghiogheny coal 65.14 per cent., and Despard coal 24.55 per cent.....	4.80	10752	19.00	91.20
Coed-talon Cannel 8.76 per cent. You- ghiogheny coal 82.27 per cent., and Murphy Run coal 8.97 per cent.....	4.93	11043	20.81	133.18

Nassau Gas Works,
F. S. BENSON.

MIXTURES OF COAL AND CANNEL.

Name of coal and percentage used.	Yield per lb. Cub. feet.	Yield per Ton. Cub. feet.	Candle Power	Candle Feet.
English Cannel .1 per cent.				
Cannelton " 5.1 " "				
Westmoreland coal 77 2 per cent.				
Youghiogheny " 14 1 " "				
Despard " 2.4 " "				
Ritchie Mineral " 1.1 " "	5.10	11424	16.30	83.13
Penn. coal 68 per cent. Crescent coal W. Va., 20 per cent., and —————				
Bog Head 12 per cent.	5.0	11200	21.50	107.5
Penn. and Westmoreland 88 per cent. Hopetown Cannel 12 per cent.	5.3	11872	21.80	115.54
Penn. coal 87 per cent. Crescent, W. Va., 5 per cent., and Cannelton Cannel 8 per cent.	5.2	11648	21.70	112.84
Penn. and Westmoreland 50 per cent. Montauk, W. Va., 19 per cent. Crescent, W. Va., 22 per cent., and —————	5.0	11260	21.25	106.25
Cannel 9 per cent.				
Penn. and Westmoreland 50 per cent. Montauk, W. Va., 52 per cent., and Ince Hall Cannel 8 per cent.	5.0	11200	20.50	102.5
Cannelton Cannel 6.37 per cent. West- moreland coal 93.63 per cent.	5.11	11446	16.45	84.05

BRECKENBRIDGE CANNEL.

This cannal probably one of the richest in the world, was better known twenty-five years ago than it is at present, the mines having been unworked for several years. Before the discovery of Petroleum, it was used for the manufacture of illuminating oil, for which purpose it had no competitor but the now exhausted Albertite of New Brunswick.

One ton of the Breckenbridge cannal will yield about 80 gallons of illuminating oil, 12 gallons of paraffine oil, besides other products.

This cannal is noted for its perfect purity, regular fracture, strength and compactness.

Its peculiarities are :

1st. The ease with which it ignites, enabling it to burn on the hearth of a common fire place, such as used for wood. A single lump once ignited will continue to burn until it is all consumed. No shavings or paper are required to ignite it—it will burn easily from the touch of a lighted match. Its combustion is attended with intense heat, and most brilliant, voluminous flame.

2d. The entire absence of loss from transportation, and repeated handling.

3d. Its resistance to atmospheric influences—frost, rain, &c., by which slacking is avoided.

A chemical analysis made under unfavorable circumstances, reveals the following percentages :

68½ per cent. of volatile matter.

27 per cent. of carbon.

8½ per cent of ash, and about

1 per cent of water.

Recent experiments show over 70 per cent of volatile matter and 7 per cent of ash,

Of sulphur there was scarcely a perceptible trace, and it is entirely free from slate.

The cannal is mined in Breckenbridge and Hancock Counties, Ky., and the shipping station is Cloverport, Ky., on the Ohio river, which is connected with the mines by railroad.

It is claimed for this cannal that one gross ton will

Yield 10000 ft. of 75 candle gas,

or 12000 " " 60 " "

or 15000 " " 50 " "

JELICO GAS CANNEL.

This is a new cannell, just placed on the market. It comes from Newcomb, Campbell County, Tenn., near the Kentucky line. No result of practical workings have as yet been obtained, but from the appearance of the coal, it bids fair to be one of the best cannells ever discovered. Both the Breckenbridge and Jellico cannells are controlled in New York by Perkins & Co., 228 Produce Exchange,

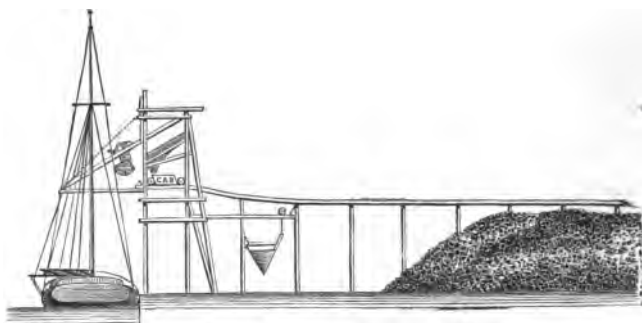
COAL HANDLING AND STORAGE.

For the benefit of Gas Engineers, a brief history of the advance made in the handling and storage of coal may not be amiss. The primitive method of unloading coal from vessels—was for the workman to carry it ashore in baskets on their heads. This method is still in use in the ports of India, Africa, and South America. The work is done by men and women, and the wages paid are only a few cents a day.

The methods in use in New Orleans and other places on the lower Mississippi at the present time are but a slight improvement on this. The coal is shoveled into wheelbarrows, and wheeled ashore on temporary plank runs. Each man takes out about six to eight tons per day.

Another step in advance was made by the erection of a mast and gaff, and using half barrels as tubs, hoisting the coal with a horse to the wheeler on an elevated run. This saved wheeling the coal up hill. The daily output averaged from ten to twelve tons per man.

The next improvement, and a valuable one was made in 1857 by Mr. Geo. Focht of Hoboken, N. J., and consisted of a peculiar shaped and balanced iron tub, now in almost universal use, that could be tipped over on one side and scraped half full; when it was righted the shovelers had only half the coal to shovel up over the side. It was also self-dumping and self-righting. This increased the efficiency of the men, and the daily output was increased from 12 to 16 tons per man.



HUNT'S COAL ELEVATOR AND AUTOMATIC RAILWAY.

The next improvement, and other succeeding ones, are due to the inventive genius and perseverance of Mr. C. W. Hunt, of 111 Broadway, N. Y. His Automatic Railway is now used to the almost entire exclusion of all other coal hoisting and handling machinery. Mr. Hunt's improvements cover the handling of the coal, and the sheds for its storage, and include. The Elevator, Automatic Railway, Dumping Cars, Steam Shovels, Steel Coal Tubs, Hoisting Blocks, Coal Tunnels, a substitute for Coal Pockets, Storage Sheds, &c., &c.

By the use of the Hoisting Elevator, much larger tubs can be used, than by the old methods, as the tubs are carried each time to exactly the same place and automatically dumped into a hopper that guides the coal into the automatic car. Using half ton tubs six shovelers work in the vessel, one man hoists and another attends to the automatic car, making eight men, handling daily about thirty-five to forty tons per man. The use of the Automatic Railway reduced the cost of storing coal to the wages of one man, but of course it did not reduce the cost of shoveling the coal into the buckets from the vessel. This has now been accomplished by the invention of the Steam Shovel, which has been the subject of experiment by Mr. Hunt for a long time. It will be seen from the cut that it works similar to a dredging machine. This shovel fills itself when lowered on the coal, and carries from one to one and a half tons at a load. It is entirely automatic, both in filling and in dumping—so that there is no one required on the vessel in any way, except at the last to scrape the coal out of the corners.

With an engine suitable for this kind of work, a round trip can be made in forty-five seconds or less, and the average will easily be one tub per minute which makes the output sixty to ninety tons per hour. With two men on the vessel, one to hoist and one



HUNT'S STEAM SHOVEL.

to attend the Automatic Car—making a total of four men, the average output per day will be at least 150 tons per man. From the above brief statements it will be seen that by the use of modern machinery, the efficiency of one man's work has been increased from 3 to 150 tons per day—or fifty to one—and the increase since 1873 when Mr. Hunt began the introduction of automatic machinery, has been ten to one—and at the same time the physical powers of the laborer are less severely taxed.

Any one who has watched the laborious work of "breaking down" into a load of coal, can understand the gain by the use of the above described apparatus.

It would be an interesting exhibition if the primitive manner of unloading coal in baskets carried on human heads, could be operated side by side with the modern machinery described above. This probably is not possible, but the operation of the modern methods can be readily seen by applying to Mr. Hunt.

COAL PRODUCTS.

Table of substances obtained in the manufacture of Coal Gas and in the utilization of the Residual Products, arising therefrom.

ACETYLENE— C_2H_2 , Specific Gravity $H = 1.297$. Boiling Point $.898^\circ F$.

Acetylene or Ethine, the first in the Acetylene series of Hydrocarbons is found in coal, and is gaseous at ordinary temperatures. Its own bulk absorbed by water.

AMMONIA— NH_3 Specific Gravity .59 Air = 1 Boiling point 27°F .

Ammonia exists in Coal Gas both in a free state and in combination. Water at common temperatures absorbs 783 times its volume of the gas. It is a strong alkali, and turns the vegetable blues to green. It neutralizes the most powerful acids and forms important salts. Gaseous Ammonia becomes liquid at -40°F .

AMMONIACAL-LIQUOR. The aqueous portion of the condensed coal products being a solution—chiefly of carbonate, sulphide, and sulphocyanide of Ammonium. Average yield of coal 25 gallons per ton of 8oz.—liquor = to 4°Twaddel .

AMYL— $\text{C}_{10}\text{H}_{22}$ One of the Hydrocarbons of the Paraffine series specific gravity 4.9 Air = 1 Density 70.85 H = 1.

AMYLENE— C_8H_{10} —One of the Hydrocarbons in coal gas, of the Olefine series. A constituent of coal tar—Sometimes called Pentylene and Pentene—Specific gravity 2.4 Air = 1 Density 34.9 H = 1.

AMYLHYDRIDE— C_5H_{12} —Sometimes called Pentane—One of the Hydrocarbons of the Paraffine or Marsh gas series—Specific gravity 2.48 Air = 1 Density 35.9 H = 1.

ANILINE— $\text{C}_6\text{H}_7\text{N}$ —The base of all dyes bearing that name.

ANTHRACENE— $\text{C}_{14}\text{H}_{10}$ —Specific gravity 6.15 Air = 1 Density 88.79 H = 1. The first of the Anthracene series of Hydrocarbons. Contained in the least volatile portion of the coal oils. It is a white solid like Naphthaline.

BENZOLE OR BENZINE— C_6H_6 —The first of the Benzine series of Hydrocarbons. One of the constituents of coal tar—a colorless limpid liquid of a very peculiar odor. Burns with a highly luminous but very smoky flame. Specific gravity 2.69 Air = 1—Density 38.91 H = 1. It is the chief constituent of Naphtha—and treated with Nitric Acid yields nitro-benzole. It dissolves resins and fats, also coal tar and pitch—forming a dark brown solution.

BI-SULPHIDE OF CARBON— CS_2 —One of the impurities of coal gas. A volatile colorless liquid, not soluble in water, removed from the gas by Sulphide of Calcium (foul gas) in the Purifiers. Specific gravity 2.64 Air = 1.

BUTYLENE— C_4H_8 —Also called Tetrylene and Butene. The third of the Olefine series of Hydrocarbons. Found in coal gas—Specific gravity 1.94 Air = 1 Density 27.94 H = 1. Gaseous at ordinary temperatures.

BUTYL-HYDRIDE— C_4H_{10} —Also called Butane and Tetrane. The fourth of the Paraffine series of Hydrocarbons. Gaseous at ordinary temperatures. Specific gravity 2.0 Air = 1 Density 28.94 H = 1. Density at 32° F. 0.60 Found in coal gas.

CARBOLIC-ACID— C_6H_6O —Also called Phenic Acid. Noted for its antiseptic and disinfecting qualities. Obtained from coal tar. Specific gravity 1.065 Water = 1.

CARBON—C—The basis of the illuminating qualities of coal gas. In the flame of Hydrogen its particles are heated to incandescence—and emit intense light. In the distillation of coal, Carbon is deposited on the interior of the retorts soon filling them up, if not often removed. It has a metallic lustre and will scratch glass. The diamond is pure carbon crystalized. "Carbon" exists in the most contrary forms. It is soft enough for the pencil sketch in the form of Graphite—and in the diamond hard enough to cut glass. In the shape of Printer's ink it expresses thought on the printed page. In lampblack it frequently takes fire spontaneously—in Graphite it resists the heat of the fiercest flame. In the diamond it is an insulator; while in charcoal it is a perfect conductor of Electricity. We burn it in our lamps and it gives us light, we burn it in our stoves and it gives us heat, we burn it in our engines and it gives us power, we burn it in our bodies and it gives us strength. It is the valuable element of all fuel, burning oils and gases.

CARBONATE OF AMMONIA— $2NH_3 \cdot 3CO_2 + 2HO$. A salt produced by the chemical combinations of Ammonia with Carbonic Acid gas.

CARBONIC ACID CO_2 —Also called *Choke damp*. It is produced by the combustion of fire damp or Marsh gas which accumulates in coal mines, and when mixed with air burns like gunpowder, forming dense volumes of CO_2 . Water dissolves its own volume of CO_2 under ordinary atmospheric pressure forming a solution of Carbonic Acid; $CO_2 + H_2O$ becoming H_2CO_3 . Is found in coal gas, and removed from it by lime. One per cent. of CO_2 in coal gas will diminish the light to the extent of about 5 per cent.—Specific gravity 1.52 Air = 1 Density 21.94 H = 1.

CARBONIC OXIDE— CO —Specific gravity .967 Air = 1 Density 13.96 H = 1. Exists in coal gas in small proportions. CO is a deadly poison.

CHRYSENE— $\text{C}_{18}\text{H}_{12}$ —A hydrocarbon of the Chrysene series—Specific gravity 7.87 Air = 1 Density 113.73 H = 1. A constituent of coal tar.

COKE—A valuable product obtained in the manufacture of coal gas. The most valuable residual product from the carbonization of coal.

CREOSOTE OR DEAD OIL—Obtained in large quantities in the distillation of coal tar. It imparts to smoke a characteristic odor, and has powerful antiseptic qualities.

CRESYLIC ACID OR CRESOL— $\text{C}_7\text{H}_5\text{O}_2$ —One of the coal tar acids.

CRUDE NAPHTHA—The first naphtha obtained in the distillation of coal tar, and which comes over at a temperature of 180 to 310 F.

CYANOGEN— C_2N_2 —Specific gravity 1.80 Air = 1 Density 26.0 H = 1. A transparent colorless gas—with a penetrating odor. Produced during the distillation of coal—and passes mostly into the tar well with the ammoniacal liquor.

DECYL-HYDRIDE— $\text{C}_{10}\text{H}_{22}$ —Hydrocarbon of the Paraffine series.	} Constituents of Coal Tar.
DECYL— $\text{C}_{10}\text{H}_{21}$ —	
DEOYLENE— $\text{C}_{10}\text{H}_{20}$ —Hydrocarbon of the Olefine series.	

ETHYL— C_2H_6 —Also called Ethane, and Ethyl-hydride. The second in the Paraffine series of Hydrocarbons. Specific gravity 1.037 Air = 1 Density 14.97 H = 1. Gaseous at ordinary temperatures. A constituent of coal gas.

HEXYLENE— C_6H_{14} —Also called Hexane and Amyl-methyl. One of the Paraffine series of Hydrocarbons and a constituent of coal tar—contained in the light oil. Specific gravity 2.97 Air = 1 Density 42.91 H = 1.

HYDROCARBONS—The different compounds of Hydrogen and Carbon gaseous or volatile, contained in coal gas and in coal tar. (See Epitome of Chemistry for table of Hydrocarbons).

NITROGEN— N —Specific gravity .9719 Air = 1 Density 14.03 H = 1. Nitrogen is a gas of a negative character. It neither burns nor permits anything else to burn. It neither supports life nor destroys it. Nitrogen in coal gas, injures the illuminating

power. It is sometimes drawn in through cracks and pores of the retort, by the action of the exhauster. The nitrogen in the coal passes off in combination with hydrogen and ammonia.

NAPHTHALINE— $C_{10}H_8$ —A very troublesome constituent of coal gas. It is of a flaky crystalline nature with a peculiar odor. It is the first of the Naphthaline series of Hydrocarbons. Specific gravity 4.423 Air = 1 Density 63.85 H = 1. It is easily dissolved by naphtha, and burns with a dense smoky flame. It is used for making lampblack, and in the "Albo Carbon Lamps," where it is made to return the illuminants back into the gas from which they were taken.

OLEFIANT GAS— C_2H_4 —Also called Ethene, Ethylene and Elayl. The second in the Olifine series of hydrocarbons—Specific gravity .967 Air = 1 Density 13.97 H = 1. Gaseous at ordinary temperatures. Exists in coal gas and contributes greatly to its illuminating power. It contains twice as much carbon as Marsh gas. It does not support combustion but is itself very inflammable, burning with a white luminous flame.

OXYGEN—O—Specific gravity 1.105 Air = 1 Density 15.96 H = 1. The presence of Oxygen in coal gas is due (like nitrogen) to the drawing in of Air, by the Exhauster, and also to the opening of the Purifiers, for charging and discharging. The amount of Air drawn in and mixed with gas, will injure the illuminating power, more or less as the gas is of a high or low candle power. Fifty per cent. of Air mixed with a 50 candle gas will totally destroy the illuminating power. (See table of the effect of Air on gases of different candle power elsewhere).

PARAFINE— $C_{17}H_{36}$ —A colorless solid, crystalline, fatty substance obtained from coal tar.

PENTYLENE— C_5H_{10} —Also called Pentene, and Amylene—Specific gravity 2.42 Air = 1 Density 34.92 H = 1. A constituent of coal tar.

PITCH—The residue left after distilling coal tar.

PROPYL— C_3H_7 —Specific gravity 2.97 Air = 1. A constituent of coal gas.

PROPYLENE— C_3H_6 —Also called Trityline, and Methyl-ethyl. Specific gravity 1.45 Air = 1 Density 20.95 H = 1. Gaseous at ordinary temperatures. A constituent of both gas and coal tar. A hydrocarbon of the Olefine series.

PYRENE— $C_{16}H_{10}$ —Also called Phenylene Naphthaline. The first of the Pyrene series of hydrocarbon. A constituent of coal tar. Specific gravity 6.98 Air = 1 Density 100.76 H = 1.

SULPHIDE OF CALCIUM—(Spent Lime). The foul lime of the purifiers and which is efficacious in absorbing from the gas the bi-sulphide of carbon impurity and the sulphur compounds other than sulphuretted hydrogen.

SULPHUR—S—Exists in the best gas-producing coals to the extent of $1\frac{1}{2}$ per cent., generally less. In carbonizing the coal about one-half of the sulphur remains in the coke while the other half is volatilized—and combining with the H and C constitutes impurities requiring removal.

SULPHURETTED HYDROGEN— H_2S —Specific gravity 1.177 Air = 1 Density 16.99 H = 1. The chief impurity in crude coal gas. It is entirely removed by the use of Lime or the Oxide of Iron. It is an inflammable gas, and generates sulphurous acid in burning

SULPHUROUS ACID— SO_2 —Also called Sulphur Di Oxide—Specific gravity 2.247 Air = 1 Density 31.95 H = 1. A gas produced when Sulphur and its compounds are burnt. Illuminating gas containing Sulphur yields it during combustion. The quantity given out is very small even with the most impure gas.

TAR—Ordinary coal tar. A complex, viscid liquid, produced in the destructive distillation of coal, and from which a great variety of valuable products are obtained. It consists almost entirely of hydrocarbon compounds, with a varying proportion of solid carbon. Coal tar on distillation, yields

on an average	2.4	per cent	ammoniacal liquor.
	1.6	" "	crude naphtha.
	1.2	" "	light oil.
	28.8	" "	creosote or dead oil.
	66.0	" "	pitch.

100.0

TOLUOLE— C_7H_8 —Also called Toluene, and Methyl benzene—Specific gravity 3.179 Air = 1 Density 45.89 H = 1. A constituent of gas and coal tar, the second of the Benzene series of hydrocarbons.

WATER— H_2O —Produced as aqueous vapor, during the destructive distillation of coal. Also one of the products of combustion of coal gas from the union of the hydrogen of the gas with the oxygen of the air.

RESIDUAL PRODUCTS

Resulting from the destructive distillation of coal.

COAL TAR.

Coal gas before condensation, has the appearance of a heavy black smoke, and becomes transparent only after the tarry matter, held in suspension, has been deposited by cooling. The greater quantity of the tarry matter is deposited in the hydraulic main, and the condensers, if they do their duty, should completely remove all traces of it, as any tar in the distributing apparatus of the scrubbers tends to stop the regular flow and even distribution of the water.

Tar is however sometimes found even in the purifiers, but its presence there shows a lack of capacity in the condensers, or bad arrangement of the apparatus.

The quantity of tar given off by one ton of coal differs greatly with the kind of coal used. Newcastle coal will yield about 10 gallons per ton. Its specific gravity is about 1.15 water = 1. It therefore sinks in water, leaving the ammoniacal liquor floating on the top.

The yield of tar at low temperatures is much greater than at high ones, as the hydrocarbons are deposited in the tar instead of passing off in the gas.

The following table gives the estimated quantities of the different products of coal tar, with their percentages of chemical composition:

Benzole.....	1.5.....	C.920—H.80	
Naphtha.....	27.0.....	C.905—H.95	
Carbolic Acid.....	5.0.....	C.766—H.64—O.170	
Cresylic Acid.....	4.0.....	C.778—H.74—O.148	
Basic Oils.....	1.0.....	C.775—H.55—N.170	
Naphthaline.....	22.0.....	C.938—H.62	
Phenanthrene.....	3.0.....	C.944—H.56	
Anthracene.....	1.0.....	C.944—H.56	
Chrysene)			
Pyrene..)	0.5.....	C.948—H.52	
Pitch ...)	35.0.....	C.960—H.10—S.5....	Ash 25
100.0			

APPROXIMATE COMPOSITION.

COAL TAR.

Carbon.....	92.0
Hydrogen.....	5.3
Oxygen.....	1.4
Nitrogen.....	0.3
Sulphur.....	0.2
Ash.....	0.8
	100.0

The most valuable of these constituents are benzine, toluene and anthracene, which exist only in small proportions.

Too rapid condensation tends to decrease the illuminating power of the gas, as the lighter hydrocarbons are carried off in the tar. The use of tar scrubbers, by means of which the gas is kept in contact with the tar for a long time, has not only helped the illuminating power of the gas, but it has proved to some extent a preventative of the formation of naphthaline.

The different forms of hot or tar scrubbers will be described elsewhere. It is a disputed question whether it is any advantage to allow the tar from the main to run in to the tar scrubber, or only that which is condensed from the gas passing through it.

The constituents of coal tar are so numerous and varied in their composition that most wonderful results have been obtained by those who have studied its chemical composition.

Most wonderful, brilliant and permanent dyes are made from it, and even a sugar called saccharine, of most intense sweetness, has been lately extracted from this complex substance.

For coating timber, and for the exterior coating of iron pipes, for roofing and paving, and other purposes, coal tar is a most useful article.

Many attempts have been made to convert it into illuminating gas, but these experiments have, after great expense and time, resulted in failure.

High heats will prevent the unnecessary production of tar, which once generated, cannot be again turned into gas.

COAL TAR AS FUEL.

In the absence of a market for coal tar it can be used as fuel, without any serious change in the furnace. It can either be injected into the furnace by a steam jet, which is probably the best way, or where steam cannot be easily obtained it can be run in from a tank, placed at a sufficient elevation to give the proper head. To change a furnace from a coke burning to a tar burning furnace, it is only necessary to remove the grate bars, door and frame, to fill up the ash pan with fire brick, and to build up the door-way, leaving a small aperture for air, over which is placed, at a slight inclination, an iron gutter.

Experience will show how fast the tar must be allowed to run into the furnace, and the proper quantity of air to properly burn it.

There are other ways of firing with tar, claimed by their users as good enough if not perfect. Mr. Geo. Anderson thus describes his method, which he has had in use for 33 years :

“The width of the furnace may be 12 or 18 inches. Turn an arch over the ash pit, with 3 or 4 inches rise, and extending from a point 6 inches in front of back wall to 12 inches beyond face of front wall of bench. The top of arch to be covered with tiles forming an inclined plane from front to rear. Under the front of arch, form an opening 9 inches square, as the furnace doorway, fitted with a sheet iron moveable door, extending up about four-fifths of the height of opening. On the outer end of the inclined tiles are placed two bricks with a space of two inches left between them and the face of bench. Loose coke is placed over this space on which the tar drops. In starting the furnace, fill it, and also the ash pit with red-hot coke, close the ash pit door and turn on the tar at the rate of 60 to 90 gallons per twenty-four hours, according to whether you have 6 or 9 retorts.

As the tar breeze forms in the furnace, push it back and remove some of the coke if necessary—in a few days enough breeze will have been made to fill the ash pit—and this must be trimmed close up to the sloping arch over ash pit, so that the air passing in must pass through the hot breeze before it enters up the space behind the slope. The fire requires attention every 3 to 4 hours.

The breeze in the furnace must be always kept red-hot, and the quantity of air admitted there, and also where the tar runs in

just what complies with this condition, and keeps a clear chimney top. A furnace of this description usually makes from 30 to 40 lbs. of breeze every 24 hours."

The one thing needful for keeping up a steady flow of tar to a tar furnace, is that the tar must be kept warm, and not allowed to get below 80° to 90° Fahr.

Coke and tar should not be burned in the same furnace, nor should there be any retort directly over the furnace, or at least not within three feet of it.

Benches have been entirely melted down by tar fires, and again others have been abandoned for want of heat, but this is the record in many other departments of gas making. The engineer quoted above also says: The successful burning of tar, without smoke, without clinkers, without too much or too little heat, is one of the simplest things a manager has to do, and certainly the easiest fire a stoker has to attend to.

As the writer above quoted is good authority, and an engineer of world-wide reputation, it would seem that at the present low price obtained for coal tar, it would be worth experimenting more on its use as fuel.

In this country, as far as the writer's observation goes, it has not been thoroughly burned, even when steam has been used with it.

It will be noticed from the description of Mr. Anderson's furnace that the air supply or at least the greater part of it, is heated by passing through the red-hot breeze below; this perhaps is the principal point in the successful result obtained by him.

In the use of tar above described, the comparative value of the tar is given as 90 gallons of tar = 1 chaldron (say 12½ cwt.) of coke.

An American engineer gives his opinion below after a long test, favorable to the use of tar as fuel when the price was low:

"The following are some and probably the principal reasons for the superior efficiency of tar fuel.

1. The combinations of combustion are more perfect.
2. The waste from incomplete combustion is less.
3. The continuous firing prevents the cooling of the furnaces by blasts of cold air.
4. There is little loss of fuel during clinkering, where with coke the loss is large.

The comparative value of the two fuels was found to be—

One bushel of coke = 1.91 gallons of tar.

One pound of tar = 2.20 lbs. of coke.

The following actual results from the use of tar as fuel are given in condensed form:

One tar bench of 5 retorts consumed $2\frac{1}{2}$ bbls. of tar in 24 hours, and carbonized 6480 lbs. of coal.

One coke bench of 5 retorts consumed 46 bushels of coke in 24 hours, and carbonized 5926 lbs. of coal.

To carbonize same amount of coal in coke bench as in tar bench would take $\frac{6480 \times 46}{5926} = 50$ bushels of coke.

50 bushels of coke at $9\frac{1}{8}$ cts per bushel is worth \$4.53.

If we let x = the actual value of the tar per bbl. when used as fuel in place of coke at $9\frac{1}{8}$ cts. per bushel or \$4.53 per 50 bushels we have $2.33 \times x = \$4.53$ and $x = \frac{\$4.53}{2.33} = \$1.94$ per bbl. Consequently when coke is worth \$4.53 per 50 bushels or $9\frac{1}{8}$ cts. per bushel, tar is worth for fuel, \$1.94 per bbl.

ANALYSIS OF 40 GALLONS OF CRUDE COAL TAR.

40 gallons of Crude Coal Tar	{	$\frac{1}{2}$ gallon light oil....	{	$\frac{1}{2}$ gallon benzole.
			{	$\frac{2}{3}$ " naphtha.
			{	$\frac{1}{6}$ " carbonic acid.
	{	$9\frac{1}{2}$ gallons heavy oil.	{	$8\frac{7}{10}$ gallons creosote oil.
		29 " pitch.....		$\frac{9}{10}$ " anthracene.
		Light oil = $3\frac{1}{2}$ per cent.		
		Heavy " = $23\frac{1}{2}$ "		
		Pitch, = $72\frac{1}{2}$ "		
		100		

TAR PAVEMENTS.

A good home market for coal tar, foul lime and breeze, and even for clinkers, may be created in almost any locality, except in places too far north where heavy frosts operate injuriously to tar pavements.

Let the engineer or superintendant go into the business of laying tar pavements, beginning at or in the vicinity of his own works. It will not be long before a demand for them will spring up, and the business increase rapidly.

When the proper time arrives, and a steady market has been created for these waste products, some one can be readily found to take the business off of his hands, he only selling them the prepared mixture at a fair price. This has been done at many places and need not be considered as an experiment.

The best mixture for the purpose consists of two-thirds breeze and one-third foul lime, with a sufficient quantity of tar to form a cohesive mass; this makes a good pavement for side walks, park walks, etc., where there is not too heavy a traffic, as in busy streets of a large city.

The mixture should be spread on a prepared bed of cinders, or small stones, 3 inches deep, if on gravel, and 2 feet deep if on loam, well rammed down, finished on top with a coating of fine sand, and finally rolled with an iron or stone roller.

The pavement is better where the mixture is put on in two or three separate layers—the whole being from 3 to 4 inches thick.

Another method is to coat the first bed of small stones or clinkers with tar; roll this thoroughly, and finish with a top dressing of coarse, sharp sand and fine coal ashes mixed together dry, in the proportion of one part of ashes to two parts of sand, and the whole thoroughly mixed with tar. Too much tar will prevent the hardening of the pavement, and too little tar will prevent the particles of sand from adhering to each other.

When thoroughly mixed, the pile should have a dry, spongy appearance. The mixture is laid down about $1\frac{1}{4}$ inches deep, well rolled and allowed to stand 24 hours or more before using.

The tar, also the ashes and sand, should be heated in very cold weather.

RESIDUAL PRODUCTS.

AMMONIACAL LIQUOR.

This residual or by-product in the manufacture of gas is often neglected and allowed to waste, where it might become a source of revenue. If allowed to pollute the water courses, it is a nuisance to the community. About one-third of the ammonia from the coal remains in the liquor, the remainder passing off with the gas, to be taken out by the action of the water in the scrubber. The yield of liquor from ordinary coal is about 10 gallons per ton.

Water at ordinary temperatures having a great affinity for ammonia (absorbing about 700 times its volume of ammonia gas), advantage is taken of this fact, and water alone is generally used

for this purpose, but on account of its deterioration of the illuminating qualities of the gas, as well as reducing the strength of the ammoniacal liquor, it is used in as small quantities as possible.

This is affected by the use of tower scrubbers and other forms where the gas is kept in contact with the strong liquor as long as possible, in order that the water may be thoroughly saturated with the ammonia.

The strength of the liquor, upon which its value rests, is ascertained roughly, by the use of Twaddel's hydrometer.

It is usual to speak of the strength of the liquor, according to the quantity of sulphuric acid H_2SO_4 required to neutralize one gallon of the liquor; thus if not less than 10 ounces of acid is necessary for that object, it is then called 10 ounce liquor.

The ounce strength corresponds with the degrees of Twaddel's hydrometer, that is each degree indicates 2 ounce strength of the liquor. In using the Twaddel hydrometer, the temperature should be 60° Fahr. If the temperature is higher, the reading will be less than the truth and *vice versa*.

The following table gives the degrees of Twaddel, specific gravity, weight and ounce strength.

TABLE OF THE DEGREES OF TWADDEL'S HYDROMETER, SPECIFIC GRAVITY, WEIGHT AND OUNCE STRENGTH.

Degrees of Twaddel.	Specific Gravity, Water = 1.	Weight per Gal. in lbs.	Ounce Strength.	Degrees of Twaddel.	Specific Gravity, Water = 1.	Weight per Gal. in lbs.	Ounce Strength.
0.5	1.0025	10.025	1	6.5	1.0320	10.325	13
1.0	1.0050	10.050	2	7.0	1.0355	10.350	14
1.5	1.0075	10.075	3	7.5	1.0370	10.370	15
2.0	1.0100	10.100	4	8.0	1.0400	10.400	16
2.5	1.0125	10.125	5	8.5	1.0425	10.425	17
3.0	1.0150	10.150	6	9.0	1.0450	10.450	18
3.5	1.0175	10.175	7	9.5	1.0475	10.475	19
4.0	1.0200	10.200	8	10.0	1.0500	10.500	20
4.5	1.0225	10.225	9	10.5	1.0525	10.525	21
5.0	1.0250	10.250	10	11.0	1.0550	10.550	22
5.5	1.0275	10.275	11	11.5	1.0575	10.575	23
6.0	1.0300	10.300	12	12.0	1.0600	10.600	24

As the liquor contains a large quantity of water in combination with a limited quantity of ammonia—and as the whole bulk of the water must be raised to expel the ammonia—this fact, together with the cost of transportation, renders it desirable, that the liquor should be as strong as possible. It is ordinarily sold to the manufacturer at 8 to 10 oz. strength.

The Twaddell hydrometer test, while fairly accurate, and answering well enough for ordinary requirements, is not perfectly reliable, therefore the strength of the liquor is sometimes tested by *alkalinity*, that is by measuring the ammonia by the amount of acid it saturates, which is a much more accurate process if carefully carried out.

For this purpose it is customary to employ a standard sulphuric acid of such strength that one gallon contains exactly one one pound (16 ounces) of sulphuric acid H_2SO_4 .

This is made by weighing out 16 ounces of the acid (or rather 16 ounces of commercial oil of vitriol) and diluting it with water, until the volume of the cold diluted acid equals one gallon. The strength of the acid must then be verified. It is called standard 16 oz. acid.

A standard 16 oz. alkaline solution, made with caustic potash or soda, should be used for the alkali standard, which must exactly match the acid standard. This is tested by actual experiment. Sensitive litmus solutions are used with these standard solutions, and burettes divided into one-sixteenth oz. divisions, and holding 2 oz. are usually employed in making the above tests.

Two methods of testing are used. 1.—By *saturation*. An accurately measured ounce (16 divisions) of the liquor to be tested, is placed in a white porcelain vessel. The burette is filled with the standard acid, which is allowed to run into the liquor, until a strip of blue litmus paper is turned red. As the acid is added, effervescence takes place, owing to the escape of carbonic acid and sulphuretted hydrogen.

A defect of this method is that the fixed ammonia is not indicated by the method of simple saturation.

2.—By *distillation*. When properly carried out this is the best and most trustworthy process.

One accurately measured ounce of the gas liquor is placed in a suitable flask, and to it an ounce of caustic soda solution is added.

The cork with delivery tube is then inserted into the neck of

the flask. Heat is then applied to the flask by means of a Bunsen burner, and the ammonia distilled into water, to which an accurate half ounce measure of standard acid has been added.

A few drops of litmus solution are added to the weak acid. The distillation is to be continued until no more ammonia comes over, which is proved by allowing a little of the steam to escape through a side tube, and testing the vapor with tumeric paper. In the case of strong gas liquor, the ammonia will presently saturate the half ounce (eight measures) of the acid, and the red color of the litmus will change to blue. More acid is then to be measured into the receiver, and ultimately the last adjustment may be made with measured standard alkali, or standard alkali may be altogether dispensed with.

Tanks for the storage of gas liquor should be covered if possible with earth, and the liquor should be fed and drawn off from the bottom to avoid stirring the surface, which increases the evaporation.

In some works the liquor is manufactured into sulphate of ammonia, and in others it is concentrated into aqua ammonia.

A description of these processes would occupy too much space for a work of this kind.

COKE.

The larger proportion of the coal used in gas-making is not volatilized, but remains as a fixed residuum or coke. This is the most valuable of all the residuals, and is a considerable source of revenue to a gas company. One of the great advantages of regenerative furnaces is the great saving of coke in the furnaces. Where the coke is drawn directly from the retorts into the furnaces, the cooling down of the furnace heat is avoided and a uniform heat is obtained. It is usually estimated that a ton of coal should yield 36 bushels of coke, but as will be seen by the results of some experiments, made at the Manhattan Gas Co.'s Works, N. Y., that the average amount of coke from caking coals (American and Provincial) was 41 bushels per ton. (See table, &c., at end of this article.)

The yield of coke from cannel coals is less, but the weight is greater than that of caking coals.

On account of its fuible nature, coke diminishes greatly in volume when kept for any length of time; it is therefore advisable to regulate the price to suit the demand so that the coke yard shall be kept clean of accumulations.

Many gas managers break up the coke either by machine or by hand hammers of peculiar construction, to adapt it to cooking purposes; the coke as it comes from the retorts being generally in pieces too large for use in stoves. A coke hammer that is extensively used for reducing the pieces to a small and uniform size is the invention of B. J. Allen, Superintendent of the Newark Gas Light Co.

The breeze or fine coke is generally used for steam making purposes, and where a blower is used it answers the purpose well.

Coke should be quenched out of doors if possible, as the sulphurous fumes are not only very disagreeable in the retort house, but they also rapidly destroy the iron beams of the floor (when quenched in the cellar), and any other wrought iron work that may be subjected to them.

*COKE OBTAINED FROM DIFFERENT COALS.

EXPERIMENTS MADE AT THE MANHATTAN GAS WORKS, NEW YORK. 1870—1875.

Name of Coals. Caking Coals.	Location of Mine.	Date of Test.	Bush. of Coke per Ton of Coal.	Lbs. of Coke per Ton of Coal.	Lbs. of Coke per bush.	Remarks.
Block House....	Nova Scotia.	1871-8	41	1504	36.68	Av'ge.
International....	" "	1871	39	1500	38.46	
Lingan	" "	1871-5	41	1450	35.37	Av'ge.
Penn.....	Pa.....	1871-8	42	1550	39.90	
Westmoreland...	Pa.....	1871-8	42	1550	36.90	
Newburgh Orrel.	W. Va.....	1871-5	43	1540	35.81	
West Fairmount.	" ".....	1873	41	1520	37.07	
Youghiogeny..	Pa.....	1874	42	1500	35.72	
Waverly.....	W. Va.....	1874-5	43	1500	34.90	Av'ge.
Clover Hill.....	" ".....	1874	42	1600	38.09	
Marion	" ".....	1874	41	1485	36.22	
Tryconnel	" ".....	1875	41	1500	36.58	
Cannels.						
Cannelton.	W. Va.....	1872-9	32	1320	41.25	
Peytona	" ".....	1872-9	32	1350	42.19	
American.....	Ohio.....	1870	38	1440	37.90	
Darlington.....	Beane Co., Pa	1869	32	1320	41.25	
Lochore	Scotland....	1872	26	1200	46.15	
Ritchie Mineral..	W. Va.....	1870	26	960	36.92	

*Paper read before the Society of Gas Lighting Dec. 1879, by G. Warren

The coke was weighed hot, and the bushel used in all the measurements was the *heaped* bushel which is a true cone $19\frac{1}{4}$ ins. diam. at the base, and 6 ins. high, added to the standard bushel of 2150.42 cubic ins.

The heaped bushel thus contains 2747.7 cubic inches.

The practical difficulty of using any heaped measure without exceeding the lawful cone of $19\frac{1}{4} \times 6$ inches has led to the adoption of a larger measure, which can be used *struck*, but which will contain cubical contents equal to some fixed number of *heaped* bushels.

All the measurements in the above table were made with such a measure, $23\frac{1}{4}$ ins. diam. and $19\frac{1}{4}$ inches deep inside measure, which holds 3 heaped bushels when used as a struck measure.

The coke was weighed before quenching.

Taking the caking coals of the table, the average of all the results, gives the following: 41 heaped bushels of coke per ton of coal, which weighs 1512 lbs., or an average of 36.88 lbs. per bushel.

THE FOLLOWING TABLE SHOWS THE RESULTS OF RECENT COMPARATIVE TESTS,
MADE WITH COKE AND FINE COAL OR "SLACK" UNDER
STEAM BOILERS IN ENGLAND.

Duration of Test.	FUEL.		Cost of Fuel per Ton 2240 lbs.	Total Water Evaporated.	Water Evaporated per lb. of Fuel.	AVERAGE TEMPERA- TURE.		Cost of Fuel per 1000 Galls. of water Evaporated	REMARKS.
	Description.	Total used.				Atmosphere.	Feed Water.		
Hours.		Pounds.	\$ Cts.	Gallons.	Pounds.	Deg. F.	Deg. F.	cts.	
164	Coke.	22,447	1.70	20,742	9.24	61	107	18.8	{ One boiler used in these tests.
90½	Slack.	13,450	1.33	9,253	6.88	51	110	86.2	
177½	Coke.	63,728	1.70	48,831	7.66	44	97.5	98.6	{ Two boilers used in these tests.
120½	Slack.	53,424	1.33	32,774	6.13	47½	100	96.8	
216	Coke.	45,388	1.70	35,514	7.82	44	138.8	96.4	{ One boiler used in these tests.
270	Slack.	79,744	1.29	45,496	5.70	49	141.1	100.8	

COMPARATIVE VALUE OF COKE AND OTHER FUELS FOR GENERATING STEAM.

Experiments Nos. 1 and 2 were made without a blower, and the remainder with a blower. In the first two experiments a grate with a flat, smooth surface pierced with holes was used ; in the remaining experiments, the ordinary grate bars were used.

No. of Experiment.	Material.	Time hours.	Quantity of fuel lbs.	Water evaporated lbs.	Water evaporated per lb. of fuel
1	Coke.....	48	2175 = 56 Bush.	16.425	7.55
2	Coal.....	48	2380	17.520	7.36
3	Coke.....	72	4058	28.105	6.92
4	Carbon....	72	3369	26.645	7.91
5	Breeze.	48	2262 = 39 Bush.	12.297	5.71
	Coke.....	48	369	2.768	7.50
6	Screenings. .	48	3047	15.760	5.17
	Coke.....	48	40	300	7.50
7	Coal dust....	48	1921	11.090	5.77
	Coke.....	48	614	4.605	7.50

EXPERIMENTS.

No. 1. Dry coke weighing 38.8 lbs. per bushel.

“ 2. Coal used, hard Lehigh egg.

“ 3. Coke contained some water, wt. about 41 lbs. per bu.

“ 4. Ordinary Retort carbon, pieces about 6 ins. long.

“ 5. Coke dust, wt. 58 lbs. per bushel.

“ 6. Screenings from refuse under furnace fires.

“ 7. Coal dust from coal-yard, cost \$1.25 per ton of 2000 lbs.

Value of each sort of fuel used as above, per ton of 2000 lbs.

Coal being estimated at \$5.00

Evaporative power per lb.	Value per ton of 2000 lbs.
Coal..... 7.36	5.00
Coke..... 7.55	5.13 or 9.96 cents per bu. of 38.8 lbs.
Carbon..... 7.91	5.37
Breeze..... 5.71	3.88
Screenings... 5.17	3.51 or 11.2 cents per bu. of 58 lbs.
Coal dust.... 5.77	3.92

BUILDING MATERIALS, ETC.

NUMBER OF CUBIC FEET OF VARIOUS EARTHS IN A TON.

Loose earth... 24.	Clay.....18.6	Clay with gravel, 14.4
Coarse sand....18.6	Earth & gravel, 17.8	Common soil....15 6

MEASUREMENT OF STONE WORK.

1 PERCH—MASON'S OR QUARRYMAN'S MEASURE.

16½ feet long,	}	= 22 cubic feet.—To be measured in wall.
16 inches wide,		
12 " high,		
16½ feet long,	}	= 24-75 cubic feet.—To be measured in pile.
18 inches wide,		
12 " high,		
1 cubic yard = 3 by 3 by 3 feet = 27 cubic feet.		

BRICKS REQUIRED FOR WALLS OF VARIOUS THICKNESS.

NUMBER FOR EACH SQUARE FOOT OF FACE OF WALL.

Thickness of Wall.	No. of Bricks.	Thickness of Wall.	No. of Bricks.
4 inches.....	7	24 inches.....	42
8 "	14	28 "	49
12 "	21	32 "	56
16 "	28	36 "	63
20 "	35	40 "	70

Good ordinary brick work may be safely loaded up to 8 tons per square foot. Brick work of the best description laid up in Portland cement can be loaded with double this weight.

Ordinary North River brick when laid should measure 2 feet high for 9 courses, which can be reckoned as 2½ inches for 1 brick and joint.

1000 brick require 1 bbl. good lime and 2 loads sand.

Lime absorbs in slacking, a mean of 2½ times its volume, and 2½ its weight of water.

Sand used for mortar or concrete should be sharp and absolutely free from all loam, earthy or vegetable matter.

MORTAR AS PER BUILDING LAWS OF THE CITY OF NEW YORK.

For lime mortar.....3 parts of sand to 1 of lime.

For cement mortar.....2 “ “ to 1 of cement.

CONCRETE USED IN CONSTRUCTION OF THE EAST RIVER BRIDGE.

One part of cement.

Two parts of sand.

Four “ “ broken stone.

CONCRETE.—NORTON'S CEMENT.

One part cement,	}	240 lbs. lime = 1 cask will make 38 cubic feet of stiff paste.
Two parts sand,		
Three “ gravel,		
Four “ broken stone,		

CONCRETE.

The volume of interstices in broken stone is equal to about
50 per cent. of its bulk.

Dry cement when mixed with water is reduced 10 per cent.

Dry sand when mixed with water is reduced 20 per cent.

Hence 1 bbl. cement will make 0.90 bbls.

And 2 bbls. dry sand “ “ 1.60 “

Total.....2.50 “

This will make enough cement mortar to fill the interstices in
5 bbls of broken stone which contains $2\frac{1}{2}$ bbls. of interstices.

As it is always better to have an excess of cement mortar, the
concrete should be made as follows:

1 bbl. cement.

2 bbls. sand.

4 “ broken stone.

In this mixture there will be $2\frac{1}{2}$ bbls. cement mortar to fill
the 2 bbls. of interstices in the stone.

THE ADHESIVE POWER OF CEMENT MORTARS.

EXPERIMENTS MADE AT SYDNEY, N. S. WALES BY PROF. WARREN:

Tensile strength of the cement used, tested alone, was 607 lbs. per square inch after 7 days, and 740 lbs. per square inch after 28 days.

DESCRIPTION OF MATERIALS.	MEAN ADHESIVE STRENGTH IN LBS. PER SQUARE INCH.	
	After 7 Days.	After 28 Days
Neat cement.....	168	213
Crushed sandstone & cement, 1 to 1	117	146
“ “ “ “ 2 “ 1	53	73
“ “ “ “ 3 “ 1	26	48
“ “ “ “ 4 “ 1	16	45
Blue stone dust “ “ 1 “ 1	79	136
“ “ “ “ 2 “ 1	47	84
“ “ “ “ 3 “ 1	34	45
“ “ “ “ 4 “ 1	23	41
River sand “ “ 1 “ 1	102	105
“ “ “ “ 2 “ 1	38	45
“ “ “ “ 3 “ 1	20	24
“ “ “ “ 4 “ 1	9	14

2½ bbls. of Rosendale cement will lay 1000 bricks.

308 lbs. of finely ground cement will make from 3.7 to 3.8 cubic feet of stiff paste. 300 lbs. net is the standard bbl. of cement, but it usually weighs 308 lbs.

1 cubic foot of dry cement powder, when loose, will measure .78 to .8 cubic feet when packed, as at manufactory.

TENSILE STRENGTH OF VARIOUS CEMENTS, MORTARS AND MASONRY.

WEIGHT OR POWER REQUIRED TO TEAR ASUNDER ONE SQUARE INCH.—GEN'L GILMORE, U. S. A.

[BRICK AND GRANITE MASONRY—320 DAYS.	MATERIALS AND MIXTURES.	ULTIMATE RESISTANCE. Lbs.
Cement—Delafield and Baxter.....	Pure..... Cement...4 } Sand...1 } Cement...5 } Siftings...1 } Cement...1 } Siftings...2 }	.. 68.56 68.5 79.87 74.5
" Lawrence & Co.	Pure	87.87
" James River.....	Pure	53.68
" Newark Lime & Cement Co. }	Cement...4 } Sand.....1 } Pure	62.00
" Brighton & Rosendale.....	Pure	93.25
" Newark & Rosendale	Cement...1 } Sand...2 }	39.62
" Pure upon bricks	Pure.....	80.25
" 1 sand, 1 pure upon bricks....	Pure.....	75.81
" 1 " 3 " " "	Pure.....	31.00
" Pure upon granite.....	Pure.....	16.00
" 1 water .5.....	Pure.....	7.00
" 1 " .42.....	Pure.....	27.00
" Pure upon bricks without mortar, mean.....	Pure.....	20.00
Common lime, 1 } without mortar..	Pure.....	27.00
" sand 2½ }	Pure.....	45.00
Lime paste. 1 } upon bricks....	Pure.....	6.00
Sand.....3 }	Pure.....	6.00
Lime paste.....1 } " "	Pure.....	4.18
Sand.....2 }	Pure.....	11.41
Lime paste.....1 }	Pure.....	11.41
Sand 3 }	Pure.....	11.41
Cement paste . 5 }	Pure.....	11.41

**COST OF MASONRY OF VARIOUS KINDS PER CUBIC
YARD, AND THE VOLUME OF MORTAR
REQUIRED FOR EACH. (GEN'L
GILMORE, U. S. A.)**

MORTAR.	Volume.	Lime—no Cement used.	Cement—no Lime used.	Difference of cost with Cement or Lime Mortar.	COST.	
					Lime Mortar	Cement Mortar
	Cb. ft.	bbls.	bbls.	\$ cts.	\$ cts.	\$ cts.
Rough, in rubble or gravel, from $\frac{1}{4}$ to 1 Cubic foot in vol....	10.8	.565	1.22	.90	4.10	5.00
Blocks, large and small, not in courses, joints hammer dress'd	8.1	.423	.92	.62	7.00	7.63
Large masses, headers and stretchers dove- tailed, beds and joints laid close.....	1.0	.05	.11	.08	9.00	9.08
Ordinary—courses 20 to 32 in. rise.....	1.5	.08	.17	.12	5.70	...
Ordinary—courses 12 to 20 in. rise.....	2.0	1.05	.22	.16	2.19	....
Brick... ..	8.0	.42	.9	.66	5.70	6.10
Concrete, good.....	11.0	.54	1.75	1.21	2 19	3.20
“ medium.....	9.0	.41	1.06	.65	1.56	2.21
“ inferior.....	8.0	.37	.97	.60	1.45	2.05
Rubble without mortar.....	.....	.....	.....	.....	3.00 to 3.30	.....

Cost of materials assumed as follows: Cement, \$1.25 per bbl.; lime, \$1.00; bricks, \$4.25 per thousand; sand and gravel, 80 cts. per ton; granite chips, 55 cts. per cubic yard; labor, \$1.00 per day.

All the lime necessary for any required quantity of mortar should be slacked at least one day before it is mixed with the sand. The ingredients should be thoroughly mixed, and then heaped for use as required.

MIXING MORTAR IN FREEZING WEATHER.

Salt water (brine) may be used for wetting mortar when made in freezing weather. One pound of rock salt in 18 gallons of water, when the temperature is 32° Fahr., with an additional ounce of salt for every degree of temperature below the freezing point. Masonry thus built will never be affected by frost.

RENDERING BRICK WALLS WATERPROOF.

A wash made of alum and castile soap, in the proportion of 1 part alum and 5 parts soap—applied in two coats; this costs about 2½ cts. per square foot, and is said to answer the purpose perfectly.

PORTLAND CEMENT.

Portland cement improves by age, if kept perfectly free from moisture. The longer it is in setting the stronger it will be. The cleaner and sharper the sand the greater the strength. Strong cement is heavy, blue gray in color, slow setting. The less water used in mixing up the cement the better. Brick, stones, etc., used with cement should be well soaked. Cement setting under still water will be stronger than if kept dry.

CRUSHING WEIGHT OF PORTLAND CEMENT.

IN LBS. PER SQUARE INCH—(GRANT.)

	NO. OF MONTHS MADE.		
	3.	6.	9.
Clear Portland Cement.....	3795	5388	5984
1 Cement to 1 of sand.....	2491	3478	4561
1 " " 2 " ".....	2004	2752	3647
1 " " 3 " ".....	1436	2156	2393
1 " " 4 " ".....	1331	1797	2209
1 " " 5 " ".....	959	1540	1678

**PORTLAND CEMENT WASH—FOR IRON, STONE
OR BRICK.**

Two coats of Portland cement, and two coats on top of silicate of soda wash, will put a coat on iron that will prevent any dampness getting at it. An excellent preparation for service pipes

THE RETORT HOUSE.

The Retort House being generally situated near the water is quite often built on ground that has been filled in, or on the soft ground found on the banks of salt water bays and inlets. The foundation should in such cases be built on piles. These should be driven as near together as possible on very bad ground, and not more than $2\frac{1}{2}$ feet apart on ordinary soft ground. It was formerly the custom to cover the piles with timber stringers about 10 by 12 ins., and these again covered with a double thickness of planking, laid diagonally. Upon this the brickwork was commenced. This mode of building on pile foundations has been abandoned on account of the liability of the wood to rot, where it is not always under water, the alternate wetting and drying, causing it to decay rapidly. The wall should be built on a bed of concrete commencing about 6 inches below the top of the piles, after they have been sawed off to a level and carried up to the proper height, according to the nature of the ground. The piles should be not less than 8 ins. dia. at the small end, and should be driven down to a hard bottom.

The foundations of the Benches should be entirely detached from the walls and piers of the building enclosing them. If the Retort House is built on very bad ground, the benches should be built in short ranges, parallel with the bank of the river or bay on which it is situated; by this plan of building the settlement will be less, and the range will settle evenly. Benches are sometimes built on heavy stone foundations resting directly on the piles. In such foundations flues are left on top of the stones, both transverse and longitudinal, for ventilating purposes; as the heat from the benches will descend and char the tops of the piles, if this precaution is not taken. Small flues equal to about one quarter of a brick in size should be formed in the heavy walls at ends of ranges, extending from the fire brick lining to the outside of end walls.

Cast-iron clamps for benches, particularly those that extend up to support the Hydraulic main, have been almost entirely superseded in new works, by steel rails, placed in pairs and held by short cast-iron clamps, forming nuts for the tie rods. The front vertical clamps are carried up about 16 inches above top of bench, and connected across the bench by other rails, which in turn sup-

port the longitudinal rails, carrying the Hydraulic main. The use of steel rails for this purpose is a great improvement over the old plan of using cast-iron clamps, which were liable to break at any time, and as they often extended up with an arm carrying the main, a break was a very serious matter.

The introduction of regenerative furnaces, has made a marked change in Retort House construction, the old one story structures having given way to more imposing ones of two stories. In the upper or charging floor, as it is generally called, the whole of the charging and drawing of the retorts is done, and also the drawing of hot coke directly into the mouth of furnace. The furnace doors for clinkering and the primary and secondary air ports, are located in the basement or ground floor. The surplus coke is dropped through openings in the floor either into barrows to be taken outside and quenched, or on to the lower floor. An elevated railway carrying buckets, or cars for removing the coke outside for quenching, is sometimes constructed, and can be arranged to work very effectively and at a small original cost.

The upper floor is made of cast iron plates, supported on iron beams, the upper light beams, and the main supporting beams of cast iron.

The coal is either raised to the charging floor by elevators, or dropped from a gallery above, either into bins, or directly on to the floor.

Where charging machines are used, bins with movable spouts, are arranged along the side walls, opposite to the benches.

For the charging and drawing machines, turn tables are necessary—these are platforms (with iron plates similar to the floor plates) about 14 feet diameter, and revolving on forged steel cones, arranged around a central pin. Richardson's patent turn tables have been generally used for this purpose, and are easily turned by two men with a load of 12 tons. In the matter of cheapening the manufacture of coal gas, to keep ahead of competition, mechanical stoking must play an important part, and it is well to be prepared for this, when building for the future, by putting in the tracks and turn table openings when the building is erected. The tracks should be about 4 by 4 ins., steel rails, and laid so as to be flush with the floor on top.

The iron roof should have high ventilators, and should be built with heavier iron than would be used in other buildings of like dimensions, on account of the deteriorating effects of the sulphurous vapors, constantly arising from beneath it.

Although the majority of Retort Houses, have the flues from the benches opening directly into the building, still it is a great improvement to have a detached chimney, of sufficient capacity and height to afford a perfect draught for the furnaces.

Not the least necessary item, in connection with the Retort House, is a large and commodious room, supplied with washing and closet accommodations for the use of the men employed therein. This room should also be supplied with a table and benches for use at meal times.

The drawing and charging of retorts is very hard and exhausting work, and but for the periods of rest, the men would not be able to endure it. In view of this, plenty of water and decent accommodation for washing should not be withheld from the men employed, even if they do sometimes abuse them.

RETORTS.

As the retort is the seat of production of the gas, the source from which it flows, its importance in the manufacture of Illuminating Gas is self-evident. In the early days of gas making, retorts made of cast iron were used, but they were short lived, and high heats could not be obtained. The introduction of clay retorts made it possible to increase the yield of gas, and being more durable than iron, have made its production cheaper. The first clay retorts were imported from Germany and England, but as the proper quality of clay was abundant in this country, they were soon produced, and now very few if any are used of foreign manufacture. The well known firm of B. Kreischer & Sons claim to have made the first retorts and tiles in this country. In the construction of new works of any magnitude it is good practice to use retorts of different manufactures, and from the record, of their working, the difference in quality may be found.

Retorts are made D shaped, oval and circular, and there are other special shapes, notably a bottle shaped retort used at the works of the Providence Gas Light Co., under the direction of Mr. A. B. Slater. Circular retorts are seldom if ever used in coal gas making, but are used as fixing retorts for water gas. Oval

retorts are extensively used throughout the Western States, and are undoubtedly equal if not better than Ds. Stokers working oval retorts, state that the labor of drawing one D retort is equal to that of two ovals. D retorts are now made with large corners, which almost make them oval. Ordinary retorts are generally made three inches thick, with the front end increased to four inches. The size and capacity of retorts have been much increased in late years, and the number of retorts per bench, is steadily increasing; settings of 3 and 5 retorts have been replaced in many cases by setting of 6 to 9 retorts, a change greatly favoring a reduction in the fuel account.

Retorts are made of all sizes from 12 by 20 inches upwards, and 9 feet long inside. Retorts when properly made, and burned should be free from cracks and flaws, smooth on the inside surfaces, and should give out a clear ringing sound when struck with a hammer.

Opinions differ as to the advantage of through retorts. When they are used they should be made in two pieces, with the joint in the real wall of bench, but they cannot be used in small works, as both ends must be drawn and charged at the same time. The deposit of carbon at the back end of the retort is of course avoided; more heating surface is obtained, and that at the hottest part of the bench.

ARCHES AND SETTINGS OF CLAY RETORTS.

The arches containing the settings, being expected to outlast many renewals of the retorts and furnaces, should be built in the most durable manner and of the best materials. The partition walls between benches, should be never less than 14 ins., and for heavy settings should be at least 18 inches. The arches should be made with heavy blocks, 9 by 12 by 3 to 3½ ins., for the first course, made to suit the radius of arch, above this course should be a course of ordinary arch brick, and over this again a rowlock course of red-brick. The haunches of the arches should be filled in with fire brick.

In using an elliptic arch for a bench of 6 or 9 retorts, which shape seems most fitted for those settings, the strongest form is that in which, the chord of the arch is divided into four equal parts. The two end parts form the radii for the two ends, and the two center parts taken together form the base of an equilateral triangle; the apex of which makes the center for the remaining part of the arch.

The fire brick should be laid wet, and set as close as possible together, the mortar being ground out of the joints. They should be laid in mortar made up of one part fire clay, and two parts ground fire brick. Three barrels of this mortar should lay 1000 fire brick.

The centers should be allowed to remain in the arches until they are thoroughly dry.

The front wall of bench around retorts, is sometimes built double with an air space to prevent the radiation of the heat.

Every part of the front wall of the furnace, especially around the doors and air ports should be made perfectly tight, and no air should be allowed to enter except at the air ports, where it can be properly regulated. A close attention to this matter, above all others, will insure success in the working of regenerative furnaces. Even where this is carefully attended to, it is only after some experience that the air supplies can be properly regulated, and the heats kept uniform, which is the great advantage of that style of furnace.

The number of bearings for the retorts, is a matter that few engineers agree upon, but it seems evident that no more should be used than are necessary for the complete support of the retorts; but few or many, they should be made of such shape that the weight of one retort, does not come entirely on another. One great advantage gained by the use of oval retorts, is the perfect manner in which the blocks can be keyed together and built up around the retorts; the joints being on lines drawn from the centers of the retorts.

Proper sight holes for observation and cleaning should be arranged in front wall of bench, and also opposite the return flues in the regenerative furnace, these should be provided with clay stoppers, neatly fitted to the openings.

The furnaces should be fired up after they are dry, as slowly as possible, and the retorts charged with a light charge of coal, after they have attained a dull red heat.

A good wash for the interior of the bench is composed of 6 lbs. of potassa, 2 pecks of common salt and $\frac{1}{4}$ bushel of fire clay. Mix with water and apply as common whitewash.

REGENERATIVE FURNACES.

The process of gaseous firing for heating retorts, is accomplished in a variety of ways, and the names given to them are somewhat loosely applied. The only real regenerative furnace, is

one in which, the waste gases, after having done their duty in heating the retorts, are carried backwards and forwards in flues parallel with and adjoining the flues containing the air supply to furnace, and heating the same, at the same time retaining sufficient heat to keep up the draught power of chimney. (A high authority says that a maximum draught of a chimney is produced when the escaping gases are at about $300^{\circ}\text{C} = 572^{\circ}\text{F}$. The waste products of combustion are also used to evaporate water from the ash pan, this preventing the formation of clinker. In all cases the furnace is merely a gas-producer, and the combustion with the secondary air takes place at points above the top of the fuel, and where the distribution of the heat will be most effective. In some furnaces the gases are carried some distance before uniting with the secondary air supply, and in others the combustion takes place, at points very near the top of the fuel. It will thus be seen that the name "regenerative" is a misnomer, and the proper name would be "recuperative" as the waste heats are not "regenerated" but recouped or recovered and used again. A generator furnace is one in which the secondary air supply is not heated at all, or it is heated by the furnace itself, being carried in by flues on either side, or by a series of chambered blocks forming the arch over the furnace.

From the above description it will be seen, that to be effective, a regenerative furnace, must be constructed with great care, so that there shall be no short circuiting from one flue to another, and that the furnace doors, and air ports must be air tight, and the openings into them under perfect control, so that the quantities of primary and secondary air entering the bench may be regulated to a certainty.

The aperture for the admission of the hot coke, drawn directly from the retorts, is at the top, and this opening must have an air tight cover.

The advantages secured by the use of regenerative furnaces are. The saving of fuel, variously estimated at from 10 to 30 per cent. Higher and steadier heats can be obtained, and are more easily regulated.

The wear and tear on the retorts is much less.

The labor required in attending the furnaces is much reduced as they require very little attention.

Some details of representative furnaces are given elsewhere.

FLUES AND CHIMNEYS.

According to "Box," the area of flues should be one-eighth that of the grate.

For example; the grate to a bench furnace has an area of 28 by 48 ins. = 1344 square inches, and one-eighth of this area will be 168 square ins., = area of flue. As there are usually two flues to a bench, the area of each would be $\frac{168}{2} = 84$ square inches.

For regenerative furnaces, this seems a little too small, it is better to make the flues a little too large, as any excess in size can be modified by dampers.

The draught power of chimneys as given by "Box" are :

DRAUGHT POWER OF CHIMNEYS.

Height.

10 ft	.....	0.07	inches of water.
20 "	.....	0.14	" " "
30 "	.....	0.22	" " "
40 "	.....	0.29	" " "
50 "	.....	0.36	" " "
60 "	.....	0.44	" " "
70 "	.....	0.51	" " "

In the majority of works in this country the flues of the retort stacks are opened about 6 feet above the top of the bench. This custom is not to be recommended because it is the common one, as it results in foul gases and dirt in profusion, besides being very injurious to the iron roof above. In some places a chimney extending through the roof is built at each end of the range—or each 2 benches, back to back have a chimney extending through the roof.

The best plan is to have the main flue placed under the center of the wall between the ranges of benches, and carried out to a chimney independent of the building. A chimney thus erected at the Newark, N. J., Co.'s works is as follows :

Height of Pedestal, (circular) 13 ft., dia. inside 7 ft. 6 ins.

" " Shaft, " 75 " " " 5 ft. 8 ins

Fire brick lining 9 ins. thick at bottom with 2 inch air space, and $4\frac{1}{2}$ ins. thick at top. Thickness of walls. Pedestal 2 ft. 8 in., 13 ft. high. Shaft from top of pedestal 25 ft., 2 ft. thick, then 16 ft. 20 ins. thick, then 16 ft. 16 ins. thick, then 31 ft. 12 ins. thick, then 10 ft. 8 ins. thick with ornamental brick work on top.

Bricks on outside of chimney laid with alternate header and stretcher. Ornamental brick projections at tops and iron cap made in 4 sections bolted together.

A square chimney at the East Chester Gas Works, is 80 feet high and 2 ft. 8 ins. square inside. Fire brick lining extends up to the height of 54 feet. Batter of chimney $\frac{1}{4}$ inch to 1 foot. Walls 12 ins. at top, to a point 10 ft. below, from thence 18 ft. 16 ins. thick, 18 ft. 20 ins. thick and 36 ft. 24 ins. thick. Ornamental brick cornice, and cast iron cap on top. This chimney furnishes the draught for four benches of six retorts each, with Stedman and Stanley's Regenerative furnaces.

In regard to the size of Retort house chimneys. Newbigging gives as a rule for chimneys under 70 feet height. $1\frac{1}{2}$ square inches of area for each lineal foot of retort, or say 15 ins. per mouth-piece. This is no doubt too small—although it agrees very nearly with the rule given by Box.

A round chimney will have $\frac{1}{4}$ more stability than a square one of width equal to its diameter.

CHIMNEY SHAFTS.

The diameter at base should be not less than $\frac{1}{10}$ th of the height. Thickness at top 1 brick to 25 ft. and increasing by $\frac{1}{2}$ brick for every 25 ft. If the inside diameter at top exceeds 4 ft. 6 ins. the top should be $1\frac{1}{2}$ bricks thick.

Fire brick lining, and air space, carried up to about $\frac{1}{3}$ th total height.

Batter should be $\frac{3}{8}$ inch to the foot, for tall chimneys; for short chimneys $\frac{1}{2}$ inch to the foot.

Chimneys should have cast iron projecting cap on top, and should always have a lightning rod, with good insulation.

MOUTH PIECES, STAND PIPES, ETC.

Mouth-pieces are generally made of the same shape as the retort to which they are attached, but oftentimes they are made circular, and sometimes they are made tapering, so as to diminish the size of the lid or cover, for convenience in opening and as a safeguard against leakage, any such contraction however increases the difficulty of drawing the charge. Retort lids were formerly luted with loam or clay worked up into mortar, but they are almost universally at present made self-sealing by the contact of

planed surfaces. As a natural sequence to the abolition of the luting process, they are now hinged, the securing cottar bar or other device swinging with the lid to one side. In consequence of the dripping and hardening of the tar upon the planed surface of the mouth-piece, it is necessary to have a sliding or scraping motion of the sharp edge of the lid to remove it, so that the metal contact shall be complete. Many devices have been invented to accomplish this. A most perfect one is the Green retort lid, made by James R. Floyd at the Oregon Iron Works, of New York. This lid and fastener, invented by Joseph Green, for many years a foreman at the Manhattan Gas Works, of New York, may be described as follows:—

They are generally made of the same form or section as the retort, but may be contracted at the mouth, or made in any shape required. The face of mouth piece and edge of lid are faced, scraped, ground to a perfectly tight joint and tested under pressure before shipment.

The simplicity of the fastening and the scraping motion given to the lid, before it is pressed into its seat, are its greatest merits.

The lid is hinged at its two bearing points to sockets or rings on the transverse steel bar and a U shaped bar has its two ends firmly secured to the outer ends of these sockets. The transverse steel bar is hinged to the mouth piece at one end, the other end being held by a movable hook, thus forming a fulcrum for the movable lever which is used for pressing down the U shaped bar, which gives the upward scraping motion to the lid, and finally forces it tightly into its seat.

For opening the lid, a light tap with the lever, under the U shaped bar, drops the lid from its seat when the hook can be thrown back, and the lid thrown open.

The inner or concave side of lid is stiffened with radial flanges.

These lids are used extensively, and the Chief Engineer of one of the largest works in this country, where they are in use, writes of them thus: "They are working to our entire satisfaction, show no sign of leaking; our workmen are pleased with them, and my opinion is that they are the best mouth piece and lid ever made."

Formerly retort lids were made of wrought or malleable iron, as in the days of luting they were subjected to very rough treatment.

They are now made of cast iron, and are usually made concave with inside flanges radiating from the centre. With the increase in the size of retorts, greater strength is required in the lid, and the old centre bearing, with cottar bar and screw, is replaced with fastenings having two bearings on the lid.

The mouth pieces are generally made about 16 inches deep; the bottom from $\frac{1}{4}$ to 1 inch thick, and the top and side $\frac{3}{8}$ to $\frac{1}{2}$ inch thick.

Mouth pieces are sometimes supported by transverse beams secured to the buckstaves on each side, placed under the lower ones, and the upper mouth pieces resting on adjustable supports on the top of those below.

Ascension or stand pipes should never be less than 6 inches internal diameter. To allow for the expansion of the setting and also for convenience in taking them down, the joints, on the mouth piece for the stand pipes are made with spigot and socket, and the joint is generally left unmade until the bench is desired for use; the pipe being kept in place in the socket by wooden wedges. The socket joints may also be made, a few feet above the upper mouth pieces, thus avoiding curved pipes, and allowing the pipes in immediate connection with the mouth pieces to be secured with flanges, thereby taking the weight of the socket from the mouth pieces, and making them more convenient for handling.

All the remaining joints on the stand, bridge and dip pipes should be made with flanges, planed and secured with red lead, and $\frac{1}{2}$ inch bolts.

For convenience in cleaning out the pipes the tops of the stand and dip pipes also the end of bridge pipes are generally fitted with plugs, luted with clay. A recent improvement, made by Klönne in connection with his regenerative furnace, consists of a cap or cover, covering the tops of both stand and dip pipes, and secured with hinge and cottar bar. For the purpose of shortening the cover, the stand pipe is slightly curved inward at the top.

As no sure preventative for choked or stopped stand pipes, has yet been invented, the only thing to be done, is to keep them as cool as possible, and this in some measure can be effected by

building the front wall of the bench of extra thickness, with an air passage in it. There is no doubt but that the front of the bench can be kept at a moderate temperature, by this method. In connection with the subject of mouth-pieces, &c., below are given several cements for various purposes.

CEMENT FOR JOINING RETORTS AND MOUTH PIECES.

For clay retorts. Three fourths by weight of fire clay. One fourth by weight of iron borings. When ready to connect, mix with ammonical water.

20 lbs. of gypsum (sulphate of lime) made into a pulp with water, 10 lbs. iron borings saturated with a strong solution of sal ammoniac. Mix well together till of a consistency fit for use.

THE HYDRAULIC MAIN.

The hydraulic main, one of the earliest inventions of Clegg, is still almost indispensable to the manufacture of coal gas. Its simplicity and usefulness has enabled it to hold its place against numerous inventions tending to displace it. Its form has been changed but very little, but it is now generally made of wrought iron instead of cast iron, as formerly. The most improved form of main in use has a rear chamber, sealed by the tar in the main against the gas and the openings on the top of the rear chamber, covered with plates easily opened. Through this chamber a curved tool can be inserted under the bottom of the dip pipes, and the main cleaned out without interruption to its working. A main invented by Mr. S. S. Stiness, but not patented, has the bottom inclined to the tar outlets so that the heavy tar is removed from the main as fast as made. There are also other inventions for replacing the tar drawn off at the bottom by water. The tar is sometimes also drawn off by inclined pipes below the main.

The Klonne main has a series of chambers running longitudinally through which the gas passes backward and forward over the tar several times before it finally escapes at the outlet. The main is also provided with capacious pockets at close intervals, into which the heavy tar settles, and is removed at stated times during the day, the pockets being connected with the main tar pipe.

It is of great importance to the proper working of the main that it should be sufficiently elevated above the top of the bench so as not to be affected by its heat. The bottom of the main should be at least two feet above top of bench ; this is now done very easily by the improved method of supporting the main on rails connecting the tops of the clamps or buckstaves.

THE HUTCHINSON APPARATUS FOR THE REMOVAL OF THE TAR FROM THE HYDRAULIC MAIN.

This apparatus removes the tar from the main and replaces it with an equal amount of water, and is a most effective means of preventing the formation of pitch. Its construction and operation are simple and easily adapted to existing mains, It consists of a tank placed at end of bench and connected with the main by a suitable pipe with stop cock, and also having a water supply pipe, and pipe with stop cock leading to tar well. Its operation is as follows : The tank being full of water the supply is cut off, and the stop cock on the pipe from main opened, when the tar by its greater gravity descends into the tank, forcing the water up into the main. The tar pipe is then shut off and the tar drawn out of the tank and replaced by a fresh supply of water, ready for the next time.

The plugs or covers on the top of the dip pipes should never be left open when a bench is out of action, the coarse, gritty particles always floating in the air where the flues open directly into the retort house, descend through the open pipes and are deposited in the tar, forming a hard deposit below the opening of the dip pipes.

In another place is described the use of tar scrubbers or condensers in close contact with the outlets of the hydraulic main, the light tar passing through them in close contact with the gas. In continuation of this subject, it may be said that the heavy tar should not be allowed to pass through the hot scrubber; this view is taken by several able writers, on the subject, Newbigging says: "The chief advantages believed to accrue from lengthened contact of the gas with the tar, are first, the absorption by the latter of naphthaline that would otherwise be carried forward to be deposited by reason of the decrease in temperature and other causes—in the mains, on the works and even in the street mains, services, etc., secondly, the absorption also of a considerable portion of the obnoxious sulphur and other compounds.

These advantages will not be forfeited by the direct removal of the bulk of the tar, because sufficient light tar will be left to absorb any excess of naphthaline vapor present, and even to assimilate a portion of the sulphur and other impurities. It has been assumed by some that no absorbent action is likely to result so long as the tar, with which the gas is in contact, is at a temperature of about 100° Fahr. and above, and that therefore the dip in the hydraulic main causes no diminution in the amount of hydrocarbon vapors present. It has even been assumed that the tar in the main gives off a proportion of hydrocarbon vapor, and in this way increases the illuminating power of the gas. It will be plain that this argument is altogether untenable. for it is scarcely possible to conceive that hydrocarbons, which have already been liquified at a high temperature, can again, at a lower temperature, assume the gaseous or vaporous form. There can be no doubt that the heavy tars have an absorbant action, less or more at all temperatures, being greatest at the lowest, and this being so, the passage of the gas through such tars by reason of the dip in the hydraulic main, must have a prejudicial effect upon the illuminating constituents of the gas. On the other hand where means are employed for removing the heavy tars from the main as rapidly as possible after they are deposited; the disadvantage of the dip into the lighter liquors contained therein is reduced almost to nothing."

In regard to the removal of the dip in the hydraulic main opinions differ as to its advantage or disadvantage. Many inventions have been patented in all countries for attaining this, but the majority of works still maintain a sufficient dip seal to prevent the exit of the gas while the retorts are out of action.

Quoting from Newbigging again he says: "Considering the easy application of the dip, its economy, its self-acting regularity, its comparative immunity from failure, and the safety attending its use, it is questionable whether any of the many appliances for dispensing with it offer sufficient inducements to compensate for the advantages enumerated.

The advocates of the removal of the dip seal, and the substitution of valves, have claimed the following results:

1. A larger yield and improved candle power from the same coal distilled at like temperatures.

2. A greater production of gas per mouthpiece, and a consequent saving of labor.
3. The prevention of the formation of carbon in the retorts.
4. The prevention of stoppages in the stand, bridge, and dip pipes.
5. A greater durability of the retorts.

A practical test of six years duration at the Newark Gas Light Co.'s Works, by Mr. E. Vanderpool, engineer, gives the following results :

"It has been found that the benches in which valves are used when working at the same temperature as those under seal.

1. Carbonized more coal and gave consequently a greater production of gas per mouth piece.
2. That carbon was not deposited so rapidly.
3. That there were not so many stopped stand pipes.
4. That there was a scarcely estimable improvement in the quality of the gas.
5. That the retorts did not last as long.

The pressure on the retorts used with the valves was three-tenths of an inch, and the seal on the other retorts varied from three quarters to one and a half inches."

Still another practical test of 10 years duration made by Mr. F. C. Sherman, engineer of the New Haven Gas Light Co.'s Works, gave the following results :

1. An actual saving of fifteen dollars per year in the working of each retort in the matter of scurfing.
2. An almost entire exemption from stopped stand pipes.
3. No influence whatever on the life of the retort.

The pressure on the retorts was three-tenths of an inch.

By the use of larger hydraulic mains, with improved methods of keeping them level, drawing off the thick tar as fast as made, with the dip pipes sealed in one-half inch or one-quarter inch of ammoniacal liquor, there may be nothing gained by dispensing with the seal, and this is perhaps the reason why engineers differ in their opinions of its utility.

In an old works, with small mains resting close on top of the bench, with the bench perhaps 6 or 10 inches out of level, the

main filled with pitch and heavy tar, pipes stopping up continually and the dip pipes sealed from 2 to 6 inches; the advent of any means for removing the seal during the burning off of the charge would be hailed with joy by all concerned.

The inventions for sealing and unsealing the dip-pipe have been very numerous, but none of them are used to any great extent at present. For an able article on this subject, by Frederick Lux, the reader is referred to the *London Journal of Gas Lighting* Nos. 1251 to 1255, vol. 49.

GAS CARBON.—SCURFING RETORTS.

The carbon deposited in the retorts during the carbonization of coal is of a peculiar nature and different from any other form of carbon. It is of a gray, metallic lustre, very hard and gritty, owing to its crystalline structure; its specific gravity is 1.095. It is nearly pure carbon and will scratch glass. High heats and too much back pressure are the cause of the carbon deposit in the retorts.

While the removal of this deposit is necessary to keep the retorts up to their full capacity, still if it were not for the deposit of carbon, the loss of gas from the use of clay retorts would be enormous.

The hydrocarbon vapors from the coal penetrate the walls of the retort, and are decomposed, leaving the carbon to fill the pores, making the retort practically tight.

The formation of the carbon goes on continually while the retort is in use, generally accumulating faster at the rear end than on the sides.

The removal of the carbon from clay retorts is a source of great danger to them if it is not done in the proper way.

This process called "scurfing" is most generally accomplished by the introduction of air from the mouth piece, through a cast iron pipe; by this means the carbon becomes oxydized and is then easily loosened with an iron bar.

A better way is by the introduction of steam and air—a process patented by Mr. Geo. W. Edge of the Jersey City Gas Co.'s Works. This process is thus described by Mr. E. Goddard:

"The apparatus consists of a steam-pipe connected with the steam boiler, and passing along the top of the retort benches, to

which is connected a 1-inch pipe extending out to the face of the retort mouth piece, to this is connected a $\frac{1}{4}$ -inch pipe, having on it a stop cock, and union joint to connect and disconnect the pipe readily. This steam pipe terminates at the end of a pipe 3 inches diam. and about 5 feet long, resting on the bottom of the retort, into which the steam rushes through a nozzle having a $\frac{5}{16}$ -inch outlet, at the same time drawing with it a current of atmospheric air. A retort lid is cut to fit closely around the 3-inch pipe. The plug is removed from the stand pipe, the retort being at a good working heat, and the steam turned on, being used at a pressure of from 25 to 40 lbs. to the square inch. The rush of steam carries with it a current of air, the cast iron pipe becomes heated and the steam and air rushing through it become superheated. The current strikes with great energy on the thick portion of the carbon at the rear end of retort. If the carbon deposit is thick on the first application of the apparatus it will require several hours to clean it out, but when the retort is once decarbonized, one hour's application every thirty days will be found sufficient to keep it clear of carbon.

Gas carbon burns with intense heat—it is used in the manufacture of carbon pencils for the Electric Arc lights.

THE RELATIVE VALUE OF HOT AND COLD COKE FOR FIRING FURNACES.

That hot coke drawn directly from the retorts into the furnaces is of greater value than cold coke is a fact that needs no experiments to establish. There must be a saving in fuel and labor, as the coke when used cold needs to be brought up to the proper temperature before it can be of any use in heating the retorts. What that saving is must vary according to different furnaces, and other causes not necessary to mention here.

The following experiments were made by Mr. Wm. Combe, Supt. Manhattan Gas Light Co., at their 14th Street station.

The coke used was weighed, not measured, and it was assumed that the total weight of coke made was the same in the hot coke bench as in the one in which cold coke was used.

No. of Experiment.	Coal Carbonized in 24 hours.	Total Coke made.	COKE USED.			REMARKS.
			Furnace 24 hours.	Per cent. of Amount made.	Per ct. of Coal Carbonized.	
	Lbs.	Lbs	Lbs.			
1.	7380	5115	2499	48.85	33.86	Fur. fed with cold coke
	7380	5115	2165	42.32	29.33	" " " hot "
2.	7380	5050	2476	49.03	33.55	" " " cold "
	7380	5050	2130	42.17	28.86	" " " hot "
3.	7380	5320	2445	45.95	33.13	" " " cold "
	7380	5320	1994	37.48	27.01	" " " hot "
4.	7680	5078	2122	41.78	27.63	" " " cold "
	7680	5078	1840	36.23	23.95	" " " hot "
5.	7740	5210	2207	42.36	28.51	" " " cold "
	7740	5210	1868	35.85	24.13	" " " hot "

RECAPITULATION.

37560	25773	11749	45.59	31.33	Fur. fed with cold coke
37560	25773	9997	38.81	26.65	" " " hot "

The results of these experiments show a saving of fuel by the use of hot coke amounting to $6\frac{7}{100}$ per cent. in the quantity used of the coke made, and $4\frac{6}{100}$ per cent. of the coke used when compared with the weight of coal carbonized.

STEAM STOKING MACHINES.

It is wonderful to think, that while steam power has been utilized in almost every known branch of human industry, the use of that power in the manufacture of illuminating gas has been confined to the exhauster. No one acquainted with the subject needs to be told of the exhaustive nature of retort house work. The rate of wages for this work is high, but the men rarely make full time.

Efforts have been made from time to time, in two directions for remedying this defective system of working. The *first* by substituting for the horizontal retort system, with its laborious handling of coal and coke, the vertical retort or cupola system, by means of which the coal could be raised and fed in at the top by suitable apparatus, and the coke discharged at the bottom, directly into barrows, to be taken away and quenched. Such cupolas have been invented, but never practically tried. The *second* by means of stoking machines for discharging and charging the retorts. Strange to say, although gas engineers and managers are agreed that the horizontal system of retorts is antiquated and cumbersome, yet no very great efforts have been made to replace it.

The reason for this probably is that any inventions looking to this end were made during the days of fat dividends, when competition was unknown, a season of contentment and lethargy on the part of the officers of the Gas Companies, now gone forever. Gas must now be made cheap, and of better quality than ever before, and at the same time its manufacture must be placed out of the reach of the despotism of labor which has reared its head in these later days. The last 20 years have seen more improvements in gas manufacture than the whole preceding period of its history, due to the fierce competition of new processes and rival modes of lighting.

From the earliest times in the history of Gas lighting, attempts have been made to apply steam machinery to retort house work. A brief list of names and dates will show what has been done to effect this object. In 1814, Maiben of Perth invented a "horizontal rotary retort." Mr. Clegg, in 1816 obtained a patent for a somewhat similar machine. In 1835 Mr. Brunton, invented an apparatus for feeding retorts from a hopper, the coal being pushed back by a piston, into a water sealed chamber at the opposite end.

Three years after, Grafton followed with his novel and ingenious invention of a scoop with closed ends, and sliding bottom, which while being inserted forced the coke out at the opposite end of a through retort, and as drawn back, deposited the coal of a fresh charge.

Geo. Michael then followed with his patent for a steam stoker, operating in connection with large through retorts, into which the coal was charged through openings in the arch above, the coke being pushed out with a ram beam with a cast iron head. Matters then rested for 20 years, until 1860 when H. Greene of the Bolton Works, constructed a machine to which power was communicated by a square shaft, operated by a stationary engine, and upon which shaft were spur wheels, connected with the machinery, and thus operated an adjustable rake, and a scoop to be filled by hand, but inserted and withdrawn by machinery.

During the following year Wm. Malam invented a charging scoop, which upon being moved rapidly forward, and then suddenly stopped, projected the coal into the retort. Our list is however getting too long for these pages, and we must pass over the inventions of Best and Holden in 1865, Geo. Simpson in 1867, W. T. Carpenter in 1869 and 1876, H. A. Bonneville in 1869, J. R. Farlane of Manchester in two years later, Messrs. Somerville & Robinson of Dublin in 1871, about which time the first attempts were made in this country by Mr. Thos. Rowland of the well known Continental Iron Works, who spent much time and money in experimenting on a charging and discharging machine, which travelled on rails overhead, but the details of these machines (which are somewhat complicated, and included meters for measuring the charges) are not now at hand.

Experimenters were still at work abroad, and followed each other in rapid succession. Wm. Mann of London in 1872, Wm. Foulis of Glasgow in 1873, with his "Hydraulic Stoker." Wm. Maquey of Dublin, and Wm. Richards in the same year, and also Mr. West of Maidstone, J. Maxwell of Glasgow, and Darlington and Scott. In 1874, patents were obtained by Warren & Waters, and J. Rowbotham, and in 1875 and 1876 by J. Steele and A. M. Clark, followed in 1877 by J. Warren. Hand chargers and dischargers have also been patented but are not worthy of mention. From the above enumeration it will be apparent that inventors have been at work to solve this problem, but it is evident that their machines were generally too complex, and without economy.

The latest and most successful inventor and experimenter in this field, is Capt. A. Q. Ross, whose apparatus is known as the

ROSS STEAM STOKER.

for which letters patents have been obtained in Great Britain, Germany, Belgium, France, Canada and the United States. These machines are the fruit of years of patient study and experiment, by an experienced mechanic. To a person interested in any kind of labor saving machinery the working of these machines in a retort house arranged to meet their requirements, is a delight ; the working of the rakes in the discharging machine, being a marvel of human ingenuity, A brief description of the machine is as follows :

THE DISCHARGING MACHINE.—The principal feature of the Discharging Machine, is a carriage driven by a small engine, and running on flanged wheels upon rails laid upon the retort house floor—parallel to the front of benches

The carriage is strongly constructed of beam iron, forming a platform about 8 by 14 feet. On one side of this platform are located the boiler with independent feed, safety valve, steam gauge, water tank and the propelling engine.

Located transversely across the other side is a rectangular upright frame, the horizontal braces of which, are the guides for the reciprocating traveller.

The frame consists of two vertical cast iron columns, bolted to the ends of the platform beams, and having three wrought iron pipe struts secured by one inch tie rods passing through them,

The rake bars can be raised or lowered at will, and are guided by grooved rollers, and flat faced wheels turning on studs to sustain and guide the rake bars, any one of which can be clamped to the traveller or to the rear column when not in use.

The traveller is a hollow cast iron cross head riding between the guides, upon duplicate grooved friction rollers above and below.

The motion is given to the traveller which carries the rakes in a most ingenious manner, which is the key to the successful operation of the machine, The manner of doing this is as follows. The steam cylinder, is placed opposite to the water cylinder, both having a common piston rod, and each having a piston attached to the rod, somewhat similar to a steam pump. The two ends of the water cylinder are connected by a pipe with a valve in the

center, so that the flow of the water can be nicely adjusted. The water in the cylinder, forms a cushion, alternately at each end, thus preventing any shock or jar to the machine. On the piston rod between the steam and water cylinders is a rack, working a pinion which works a chain wheel on the same shaft, and this chain being attached to the traveller, operates the same, sending it backwards and forwards and carrying the rake to which it is attached with it. The possibility of any shock from the traveller against the end columns of the frmae, is avoided by rubber buffers, but the working of the machine is so easily controlled, that it is seldom that they ever come in contact. The rake beams are of rolled angle iron, and the rake heads are steel castings suited to the shape of the retorts, and hinged to the ends of the rake beams. The whole machine weighs about 10,000 lbs., and can be introduced into any retort house having not less than 16 feet clear space between the mouth pieces and side wall—without any change or preparation other than laying the track, upon which it is to be moved:

The whole of the movements of the machine, are governed by levers operated by one man, who is stationed at the extreme rear end, out of the way of smoke or steam, and commanding a clear view of the interior of the retorts. The rakes clear the retorts, as thoroughly from coke as any human stoker can do.

The coke can be drawn into barrows, where the retort house has no cellar, or dropped through doors in the floor, or into the furnace, where regenerative furnaces are used.

THE CHARGING MACHINE—consists of a rectangular frame, made of suitable iron beams, and running on flanged wheels, similar to the other machine.

Upon one side of this platform, are located the boiler, steam reservoir, water tank and propelling engine.

Upon the other side is the supplemental carriage also moved by an engine, and travelling on rails, backward and forward for the purpose of replenishing the hoppers at the coal bins. The coal hopper is divided into three parts, each part containing a charge for one retort. The hopper on the first made machines, was raised and lowered to the different retort levels, by a wheel and pulley worked by steam and the hopper was propelled backwards and forwards by a hand wheel. All this has now been changed, and the hopper is stationary in relation to the retort levels, and its other movements are made by an engine.

Each of the compartments of the hopper are connected to a conduit below, and in the rear of this conduit is located a pipe with a series of jet nozzles, horizontally disposed, so as to discharge against the coal, and thus project it into the retort. The levers for operating the steam blast, and the other motions of the machine are all concentrated convenient to the hands of the operator.

The fundamental principle of this system of charging is a dry steam or compressed air blast, used explosively, in direct contact with the charge of coal, without the intervention of any mechanical appliances; the mechanism otherwise employed, is of the most simple and durable character, enabling a single operator, by the exercise of ordinary skill, and with but trifling personal exertion to control every movement necessary to the successful operation of the machine.

In the practical operation of these machines at the works of the Cincinnati Gas Light & Coke Co., an attendant strikes the lids from three retorts, or one-half of a bench, the discharging machine is then brought into position opposite the upper retort, with the corresponding rake pinned to the traveller, when the operator with his right hand on the lever used for controlling the vertical play of the rakes, and his left upon the valve lever of the steam cylinder actuating the traveller, elevates the guide bar to admit the rake head, into the retort above the charge, and as the rake is projected forward, should it meet with any obstruction, it folds back under the rake beam, and gains a vertical position, when the obstruction is passed or the withdrawal begins.

His position is at such a distance from the mouth piece that it gives him every opportunity for observation, unembarrassed by the heat or smoke arising from the expelled coke, and the thrust being governed by the automatic devices before referred to, his entire attention can be centered upon the direction of the movement and the vertical adjustment, perfectly governed by the two levers under his immediate control, enabling him to arrest, renew or reverse the movement, or to elevate or depress the rake head at any desired point. The tar coke is first removed by a short stroke, followed by such other movements—usually from 4 to 6—as may be found necessary to clean the retort—the whole occupying not exceeding fifteen seconds.

The Discharging Machine is closely followed by the "CHARGER" which having been coaled by chutes leading from the bins, conveniently located along the side of the retort house, is moved into position, opposite to the three retorts to be charged. The operator then discharges each compartment of the hopper in quick succession, requiring from three to four blasts to each retort, so graduated that the first blast will project a portion of the charge to the rear of the retort, the succeeding blasts, depositing the charge uniformly in front of it. The skill necessary to do this perfectly, can be acquired by any intelligent workman in a few hours. After the three retorts have been charged, the hopper is run back by its engine, to its limit of travel, the machine propelled to the nearest coal chute and the hopper filled as before.

This process is repeated as often as desired, or to the limit of the working capacity of the machine, which including recoaling, &c, will with one operator and one assistant to each machine, average over 60 retorts per hour. Out of this a certain amount of time must necessarily be allowed for rest of operator, replenishing fire, watering, oiling, &c. At the Cincinnati Gas Works, a pair of these machines have, with apparent ease, drawn and charged twenty-seven benches, or one hundred and sixty-two retorts, which with four hour charges, gives forty minutes work and twenty minutes rest.

These machines are guaranteed to work at the rate of one retort per minute, so that any one can estimate the saving by their use, this depending naturally upon the cost of retort house labor, where they are used.

In submitting facts and figures, based upon experience at the works mentioned above, it must not be overlooked that the changes, which it appears advisable to make, in order that the best possible results may be obtained, carry with them their own attendant advantages, and should therefore be credited to the machines, and not charged against them. Take for example the handling of the coal, which by the aid of suitable mechanical appliances, can be prepared, elevated, stored in bins, and run into the hopper of the machine at much less expense than is now required to place it on the retort house floor by manual labor, and if, as should always be the case, this storage capacity is in excess of the daily demand, night work always the most expensive, can be entirely dispensed with, and a constant supply of dry coal be kept conveniently near.

The cost of repairs will not be in excess of those now expended in repairing and renewing retort house tools.

The maximum working capacity of one pair of these machines can be fairly fixed at thirty benches, or one hundred and eighty retorts which gives forty-five minutes work, and fifteen minutes rest, and the operation of which will be covered by the following estimated expenses.

Interest on investment say \$10,000 @ 6 per cent.....	\$ 600.00
Depreciation say \$10,000 @ 10 per cent.....	1000.00
4 Engineers (2 day and 2 night) 365 days @ \$2.50.....	3650.00
2 Assistants (1 day and 1 night) 365 days @ \$1.75.....	1277.50
4 Lid-men (2 day and 2 night) 365 days @ \$1.50	2190.00
10 Firemen (5 day and 5 night) 365 days @ \$2.00	7300.00
Fuel, coke 30,000 bushels @ 4 cts.....	1200.00
Water, City 700,000 galls. @ 10 cts. per M....	70.00
Oils, cylinder 62 galls @ 80 cts.....	49.60
Oils, lubricating 62 galls. @ 25 cts.....	15.50
Oils, illuminating 40 galls. @ 20 cts.....	8.00
Packing, 30 lbs. @ \$1.00.....	30.00
Cotton waste, 100 lbs. @ 10 cts.....	10.00

Men 20.....cost \$17,400.60

Producing 20,491,830 cubic feet per man, at an expense of 4½ cts. per thousand.

To perform this same service under the present system of retort house labor (4 men to five benches) requires the services of 48 men (24 day and 24 night) for 365 days @ \$2.50 = \$48,800 ; producing 8,538,242 cubic feet per man, at an expense of 10.68 cts. per 1000 cubic feet, showing a saving of \$28,600 per annum on one pair of machines, or 6.43 cts. per 1000 cubic feet manufactured.

While this saving will be greater in large, and proportionately less in small works, their use can be made profitable enough to warrant immediate introduction, in any works having in action over six benches in one range.

It may be added here, that the wear and tear on the retorts, is not increased in the least degree by the use of these machines. If there are any incidental effects, one of them is that the formation of carbon is decreased.

The machines have both naturally been improved since their first introduction, the Discharging Machine, has been made of improved materials, and the changes have been slight, the main one being the enlargement of the boiler. The changes and improvements in the Charging Machine have been spoken of before, and consist in the substitution of steam for hand power in propelling the hopper, and in dispensing with the movement of the hopper to suit the different retort levels.

Below are extracts from testimonials from Engineers who have used the machines.

Gen'l Hickenlooper, President of the Cincinnati Gas Light Co. in answer to an enquiry as to the working of the machines, writes as follows:

"In response to your communication soliciting information as to our use of, and satisfaction with the Ross Steam Stokers, I would state that we have had them in use at our old works or West End Station for about five years, and at our new, or East End Station since its completion about two years ago.

They proved so serviceable and economical at the old station that the new one was expressly designed for their use. The coal being taken direct from the barges, the cars run in (by overhead trackways) and discharge into bins, from which it runs by gravity into the hopper of the machines, and is discharged by steam blast into the retorts.

The resultant coke is drawn out by the discharger, either into the furnace or through stage doors into cars beneath, is then quenched, run into coke elevator, and deposited in bins, from which the market supply is drawn. The new retort house is in two sections, but one of which has been completed. In this are fourteen double benches, with eight through retorts, set in exact horizontal and perpendicular lines, which enables the machines to perform their functions without shifting position at each retort.

We are at present operating two pairs of machines and have one pair in reserve, ready for immediate use in case of accident to the ones being operated.

These machines were built by Delemater & Co. of New York City and have operated perfectly from the start. They are capable of continuously drawing and charging 80 retorts per hour.

With our limited construction we have had no occasion to practically test their *maximum* operating capacity, but with our single range of 14 benches, 102 retorts on each side, 400 lbs. per charge, and 4 hours and 48 minutes duration of charge, they can be easily operated at the following expense per day of 24 hours.

2 Foreman	@	\$3.00	\$6.00
4 Engineers on drawing machine		2.00	8.00
4 " " charging "		2.25	9.00
4 Assistants		1.75	7.00
16 Lid men, sweepers and helpers		1.75	28.00
2 Furnace men (cellar)		1.50	3.00
8 Coke men		1.50	12.00
8 Coal men, yard and gallery		1.50	12.00
120 Bushels coke		.05	6.50
Oil, waste, repairs, etc., average			1.50

Total **\$93.00**

With 4.90 yield, 400 lb. charge, and 5 draws in 24 hours, we get from 224 retorts, 2,195,200 cubic feet.

With this statement before him, any engineer can estimate the saving due the machines stoking in any designated works. To accomplish this same work under the former system of hand labor at these works would have cost as follows:

2 Foreman	@ \$3.00	\$6.00
42 Stokers	" 2.25	94.50
14 Helpers	" 2.00	28.00
8 Coke men	" 1.50	12.00
12 Coal men	" 2.00	24.00
Wear and tear of retort tools, average	"	2.00
Total		\$166.50

A difference in favor of steam stoking of \$73.50 per day or \$26,827.50 per year.

These machine like the duties assigned, are essentially different, each being separate and independent of the other, and while my judgment is that a complete and perfect system requires the adoption of both, the discharger requires no special arrangement or change of construction in existing retort houses, possesses greater efficiency with less expenditure of power, and can discharge retorts more rapidly and economically than they can be charged."

Mr. Chas. Hunt, Engineer of the Birmingham Gas Co., England, says :

"The four Ross Drawing Machines, for some considerable time, have done the whole of the drawing in our new retort house, with scarcely an interruption, and without the necessity on any single occasion, for recourse to hand power. The total number of month pieces that have been served by the machines is 756, which charged every 6 hours, gives an average of 63 month pieces per machine every 2 hours. This however is not their limit of work, 70 being the recognized number for each machine when worked singly, and it is quite possible to attain to 80, still leaving sufficient time between the draws for clearing up, slight repairs, and the men's meals. Each machine requires one man to drive it and one attendant to open lids. 420 retorts are drawn with ease as the days work of two men.

With hand drawing I should consider 60 a fair days work per man, so that the two men with the machine do the work of 7.

To judge from our experience thus far, I do not think the wear and tear is likely to prove at all a serious item, and the expenditure of fuel I find to be as nearly as possible 9 tons of coke per week per machine, or less than $1\frac{1}{2}$ tons per 24 hours. I may add that the drawing is very cleanly and expeditiously done, and altogether I regard the machine as a valuable acquisition to any gas works of sufficient size to keep it fully employed. By the use of larger boilers the fuel has been reduced to four tons per week of $6\frac{1}{2}$ days against 9 tons previously used; the amount of work remaining the same."

Mr. Malcolm Greenough, of the Boston Gas Works, says :

"It gives me much pleasure to highly endorse the working of the Drawing machines furnished us by your Company; they have been in constant use at our new works ever since that station was started. In drawing 96 retorts every 4 hours, which have been charged with 333 lbs. of coal per mouth piece, the capacity of a machine is by no means exhausted. It would handle in my opinion at least 25 per cent. more retorts without difficulty."

Mr. E. G. Cowdery, Eng. and Supt. of the Milwaukee Gas Light Co., says :

"The discharging machines have been in use with us about 9 months. The best thing I can say for them is, that if to-day I did not have them I would lose no time in making the purchase."

The two machines have been in use and run by one man during the summer, caring for only 54 retorts and this winter 108 retorts. We have saved with them a little more than enough to pay the interest on the investment, which was all I expected. Next winter they will care for 300 retorts, and then begin to make us some money. I would certainly recommend any works turning out upwards of 300,000,000 cubic feet of coal gas per year to purchase these machines."

Mr. Theobald Forstall, of Chicago, says :

"The machines at our works are satisfactory in their operation and results, having enabled us to do with 58 men the work which it required 90 men to do without them under our 8 hour system."

Mr. A. M. Smith, Supt. of the 18th St. Station, of the Consolidated Gas Co., of New York, says :

"We have had 8 of the discharging machines, furnished by your Company, in constant use during the past 6 years, and are fully satisfied as to their economy and durability."

It will be noticed that at the Milwaukee Gas Works, the engineer finds it profitable to use the machines in the summer when he has only 54 retorts in action.

As before stated, the changes necessary in a retort house for the introduction of the Discharging machine, and the perfection with which that machine does its work, has caused its adoption, where the introduction of the Discharging machine would have entailed too great an expense for coal elevators, bins, etc. The Charging machine as originally made also required more skillful manipulation, but with the improvements now added to it, there is no reason why it should not be worked as easily and economically as the Discharging machine.

THE MUNICH REGENERATIVE FURNACE AND BENCHES.

The principal feature of this bench is the position of the furnace, which is entirely outside the retort stack, and communicating with it by an inclined duct. The whole interior of arch under the retorts is occupied by the regenerative arrangements.

The generator is divided into four distinct parts: 1st.—The lower part where the steam is generated and the primary air is introduced. 2d.—The space between water pan and grate bars to receive the ashes. 3d.—The fuel chamber. 4th.—The part directly beneath the charging chute. The primary air enters at ports regulated by dampers, at the point where the steam from the water pan (which is covered under the grate bars) enters the bench, with which it mixes, and after traversing flues heated by the spent gases, it enters the back of generator and ascends to the zone of combustion. The generator gases ascend through the duct leading into bench where they meet the secondary air previously heated in the regenerator. The combustion chamber extends the whole length of bench below the level of lower retorts; the products of combustion pass around the retorts in the usual manner and by numerous flues, heating the primary and secondary air, finally find an exit (after passing under water pan) into the main flue at the back of bench.

This system of regenerator furnace is extensively used in Europe, and the advantages claimed for it are:

1st.—The prevention of clinker by the decomposition of steam in the generator.

2d.—The volume of steam generated by the products of combustion is strictly proportional to the amount of fuel in the generator.

3d.—The heat abstracted from the generator to decompose the steam is carried into the bench in the form of combustible gases.

4th.—Large quantities of steam can be introduced into the generator at constant rates, thus keeping the temperature below the fusing point of any earthy matter in the fuel, which is deposited on the grate bars in the form of porous ashes, and offers but little resistance to the penetration of air, even when of several inches in thickness.

The generators are cleaned out once in 24 to 36 hours, taking 30 minutes time for the operation.

Great advantage is claimed for the mixing of the air and steam, and heating them when mixed, by the products of combustion before entering the generator.

A production of 10,000 cubic feet of gas per retort (21" $\times$ 15") in 24 hours is claimed for this system, but much better results can be obtained, but at the expense of stopped stand pipes, and the production of naphthalene, which is the result of high heats in all systems.

The generators are kept at a low temperature by the steam, causing but little loss from radiation, and a very small amount of wear and tear.

An average analysis of many tests of the generator gas shows its composition to be:

Constituents,	{	Carbonic acid.....	8.6 per cent.
		Carbonic oxide.....	20.6 " "
		Hydrogen.....	15.0 " "
		Nitrogen.....	55.8 " "
			100.0

The combustible compound enters the setting at an average temperature of 1150° C (2102 Fahr.) The products of combustion leave the bench at a temperature of about 1400 C (2550 Fahr.) and consequently enters the regenerator at that temperature; after heating the secondary air to from 1000° to 1100° C (1832 to 2012 Fahr.) they still register about 900° C (1652 Fahr.) After imparting a portion of their remaining heat to the mixture of air and steam, they enter the flues under the water pan at a temperature of 550° C (1022 Fahr.)

The working results in Munich during the year 1884-5 were as follows:

Total production of gas, 9,906,060 cub. metres=349,842,000 cub. ft.
 Total consumption of coal...31,278.9 tons (net)=62,557,800 lbs.
 Total production of coke....18,865.9 " =37,731,800 "
 Consum. of coke in generator.. 3,014.9 " = 6,029,800 "

This shows a consumption of 15.1 per cent. of the coke produced or 9.6 lbs. to the cwt. carbonized.

Each bench has 8 oval retorts, 15' by 21' by 9' inside. The gas production per bench per day amounted to 2,150 cubic metres = 75,000 cubic feet or 9,375 cubic feet per mouth piece. 4 hour charges of 260 lbs. of coal.

THE STEDMAN-STANLEY REGENERATIVE AND HALF REGENERATIVE FURNACE.

These furnaces, the combined production of Mr. W. A. Stedman, late of the Newport, R. I. Gas Co., and Mr. I. N. Stanley, of the E. D. White Fire Brick and Retort Works, of Brooklyn, L. I., has met with well merited success. The regenerative arrangements differ from those of any other; the flues through which the secondary air supply and the products of combustion pass, are separated by very thin tiles, having sheets of iron between. The products of combustion after leaving the bench proper, are taken backwards and forwards through the longitudinal flues; the flues for the secondary air supply passing through similar flues placed between them and finding exit when sufficiently heated, through perforated blocks, placed opposite the nostrils over the furnace.

The products of combustion before their final exit from the bench, pass under the ash pan transversely, heating the water and generating steam, which prevents the formation of clinkers.

The furnace is charged directly from the retorts with hot coke, the furnace charging door being placed in the front wall of bench above the floor.

A stack of 22 benches of 9 retorts each, placed back to back, has been in operation in the Philadelphia Gas Co.'s Works for the past year and have given entire satisfaction, both as to economy and production.

WEBER'S HALF DEPTH REGENERATIVE FURNACE.

This furnace is adapted to meet the requirements of existing arches, and also for works situated on ground where a cellar cannot be excavated on account of the proximity of water. It is claimed for this furnace that the ease and simplicity of running are remarkable, that the heats are steady, and that the only wear on the retorts arises from the drawing and charging.

It is also claimed for them that the life of the retorts used with this furnace will be at least twice as long as those used with the ordinary furnace; the saving of coke is also great—the amount used to carbonize a charge being from 15 to 20 lbs.

The working and construction of these furnaces briefly described is as follows: The whole of the air for combustion enters

at the front of the setting and passes through flues, surrounded by the flues conveying the products of combustion to the chimney. A portion of these gases is carried under the ash pan to make steam; the steam being mixed with air, and entering into the primary combustion with the fuel in the furnace. The bottom of the lowest air flue, by which the cold air enters, is about four feet below the floor line.

The formation of clinkers is prevented by the admission of the mixture of steam and the heated primary air, and a vitreous coating is at the same time found on the brick work of the furnace.

Judging from the number of places where this system has been introduced, its success in the directions claimed for it is assured.

THE KLOENNE AND BREDEL IMPROVED REGENERATIVE FURNACE.

This furnace is used extensively on the Continent and in Great Britain. In Birmingham 952 retorts have been erected. The claims for its superiority made by its inventor are as follows: The generator and regenerator are independent of each other, so that the contraction and expansion of one does not effect the other. The superheating surface is greater than in any other furnace yet constructed. The regenerator is self-tightening and cannot get out of order. The thickness of material between the waste gases, secondary and primary air flues is only $1\frac{1}{2}$ inches. The grate surface is large and allows the use of inferior fuel, such as breeze, fine coke and slack coal.

Clinkers are never formed. By an ingenious arrangement of mixing air and steam, all incombustible materials in the fuel are converted into soft ashes.

The waste gases leave the flues at a temperature of from 400° to 500°.—No large chimneys are required.

No cold air can enter, consequently there is no cracking of the bench.

The generator is inside of bench, thereby preventing loss of heat. During the years 1886 and 1887 more than 500 retorts, with a capacity of 5,000,000 cubic feet of gas per day, have been erected in this country and are giving the best satisfaction.

Notably among others may be mentioned, benches erected for the Newark Gas Light Co., the Philadelphia Gas Works, the Milwaukee Gas Light Co., and the Chicago Gas Light Co.

These furnaces were first introduced into this country by Mr. Fred. Bredel.

THE McILLHENNY RECUPERATIVE FURNACE.

The inventor of this furnace, Mr. Geo. A. McIlhenny, of the Washington, D. C. Gas Works, is well known to the "Gas Fraternity," and he has embodied in this invention the fruits of many years of practical and experimental working in the field of regenerative firing, as applied to the heating of gas retort benches. With pains-taking care and patient skill, the various obstacles that naturally beset the advance of the investigator in a new field were met and overcome, until step by step the details of this furnace became parts of a permanent and simple system of recuperative firing for gas retorts.

The arrangement of this furnace is in brief, that of the common combination of a retort arch, having a generator or fire pot immediately beneath it and communicating with it through the usual "throat." This likeness ceases at this point as the manner of introducing the air supply for the secondary combustion is not through horizontal to and fro ducts, built in the side walls of the furnace, but by simple straight, vertical air-heating ducts, which are connected together at the base, with the horizontal air supply duct at the bottom of the side wall, and at their top enters into distributing chambers (2 in a setting of nines, and 1 in a setting of sixes) located between the top of the generator and the bottom of the retort arch. This direct conducting of the secondary air does away with all need of forcing contrivances and tall chimney stacks, to secure a constant and sufficient supply of air to properly consume the furnace gases. The second point of interest in this arrangement of vertical air ducts is their combination in the side walls of the furnace with exit or down-take flues, through which the products of the combustion in the retort arch pass on their passage to the chimney. Usually, the rear lower corners of the retort arch have been the location of the out-take flues. In this furnace the spent products of combustion are drawn downward from the arch, and used to assist in the heating of the air which sustains the secondary combustion by being conducted

from the retort arch in straight, vertical flues, distributed longitudinally of the arch, in the side walls of the furnace, surrounding and in immediate contact with the secondary air ducts. The mouth of these down-take flues open directly into the bottom of the retort arch, and at the bottom they connect near the base of the fire pot, in a straight, horizontal flue which enters the chimney-flue at its base.

This arrangement also secures a more even distribution of circulating currents through the retort arch, thereby causing a more regular and well distributed "heat" to the several retorts; accomplishing these results without the use of artificial draughts or blowing apparatus. In operation the first care is that the furnace is made to produce the greatest quantity of carbonic oxide with least consumption of fuel; these generator gases, and the incoming heated atmospheric oxygen are then brought together in one or more centrally located longitudinal rows of openings, the main combustion taking place along the line of the bottom retort setting. The flame and heat produced passing directly upward between the retorts are affected by the draught from the series of down-take flues, and are by their action, diverted through the settings toward the sides of the arch and thence to the exit mouths of these flues, traversing in their course all parts of the retorts, and imparting to each a full portion of heat exposure.

That this furnace accomplishes the economical heating of the retorts in a simple and easily handled apparatus, the excellent yields per mouth piece and per ton, the low percentage of fuel used, the thorough carbonization of the coal, and freedom from hard clinkers in the furnace and absence of pitch from the hydraulic main furnish ample testimony. Its general arrangements of details make it the most economical in cost of construction when compared with other furnaces that approach it in results.

In its present form this furnace has been long enough in use to demonstrate its durability, its exact and regular working under all the varying circumstances to which the gas-maker can subject it.

PURIFICATION.

As it leaves the retort in which it is generated coal gas is very impure. It is accompanied by rather less than one-third its weight of tar, by nearly half its weight of watery vapor, by about $\frac{1}{10}$ th of its weight of ammonia, by a little more than $\frac{1}{10}$ th of its weight

of carbonic acid, by from $\frac{1}{80}$ th to $\frac{1}{100}$ th of its weight of sulphuretted hydrogen, and by from $\frac{1}{800}$ th to $\frac{1}{1000}$ th of its weight of sulphur in the condition of sulphuret of carbon, and organo sulphur compounds.

By condensation, washing and scrubbing, the tar is removed, the watery vapor being reduced until the gas holds just as much moisture as saturates it at ordinary temperatures and the ammonia is almost absolutely abstracted.

During condensation, washing and scrubbing, the carbonic acid, sulphuretted hydrogen, and other sulphur compounds are diminished.

At the outlet of the Condenser the gas should be free from tar, and at the outlet of the water scrubber, it should be nearly free from ammonia. The further purification is directed to the removal of sulphuretted hydrogen, sulphur compounds, and carbonic acid.

These ingredients, detrimental to its mission of illumination, are eliminated by exposing the gas to the action of solid substances contained in "purifying boxes" the gas being made to permeate the purifying material.

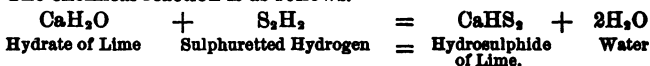
The proper arrangement for the purifying apparatus, so as to get their full benefit, should be as follows. Next to the Hydraulic main, and as close as possible to it, should be placed the tar scrubber, which should be encased in brick, or covered with some heat retaining material. The remainder of the purifying apparatus should be placed in the following order. Exhausters, condensers, scrubbers and washers, and purifiers. Some Engineers prefer to have the exhauster after the condenser, but this is a mistake, as it is better to push the gas through any of the apparatus, as by this arrangement, every part of the condensers, scrubbers, &c., are completely filled with the gas, whereas by the other system, the gas passes through the central portions in a small stream and much of the benefit of the apparatus is lost. In the exhausters at present made, the presence of a moderate quantity of tar does no harm, but rather tends to lubricate the interior of the machine. The different apparatus for condensing, scrubbing and purifying the gas, will be described under their respective heads.

The tarry vapors begins to condense in the hydraulic main, and this process continues to the outlet of the condensers, where the gas should be free from tar.

The ammoniacal liquor begins also to separate in the hydraulic main, and continues to separate from the gas until at the outlet of the scrubber the ammonia should be nearly or entirely eliminated from the gas.

A portion of the carbonic acid, sulphide of carbon, and bisulphide of carbon, is also removed by the condensers and purifiers, the bulk of these impurities are however carried forward to the purifiers.

For many years the gas has been further purified, after leaving the scrubber by means of hydrate of calcium, or slacked lime, generally made from shell lime where this can be obtained. Having a great affinity for carbonic acid, and sulphuretted hydrogen, the lime removes these compounds entirely. The lime is slacked with clean water some little time before using. If exposed too long to the air, it absorbs carbonic acid, and if placed too soon in the purifiers after slacking it is apt to cake. The hydrate is placed evenly on trays, to the depth of $2\frac{1}{2}$ to 3 inches, with about 3 inches of space between each layer. The hydrate of lime when properly prepared weighs about 50 lbs. to the bushel—and one bushel = 1.25 cubic ft. The amount of lime required to purify 1000 cubic feet of gas, depends greatly upon the character of the coal, some coals containing much greater quantities of sulphur, than others. The chemical reaction is as follows.



In some gas works, the spent or foul lime is revived or freed from the impurities it has taken from the gas—this is effected by burning the lime in kilns or retorts. A great nuisance is thus removed and a saving in the expense of purification is made. Where this is done a tall chimney is necessary to carry off the foul gases generated by burning the lime.

OXIDE OF IRON PURIFICATION.

Oxide of Iron, under the names of "Ferric Oxide," "Iron sponge," &c., is also extensively used for the removal of the impurities in the gas. As this substance has great affinity for the sulphuretted hydrogen, and very little for the carbonic acid, it is the custom to have check purifiers charged with lime, through which the gas finally passes to the station meter. Sometimes one or more tiers of trays in the oxide purifiers are charged with lime. The oxide of iron is placed on the trays about 16 inches deep.

The great advantage and economy in the use of oxide of iron for purification, arises from the fact, that it may be revived by simple exposure to the air, and turning it over occasionally so that the mass is thoroughly exposed. When taken from the purifiers it is sulphide of iron, of a dense black color, and after exposure it changes to its original reddish brown color. When it has absorbed about 56 per cent. by weight of sulphur, the material is sold.

The oxide is apt to get very hot, if not promptly removed from the purifiers.

Experiments have recently been made in London, by which the spent oxide is revived without removal from the boxes. Pure oxygen of the strength of 15 atmospheres, together with the gas, in the proportion of 1 cubic ft. of oxygen to 100 cubic feet of gas, is forced through the material by an exhauster, after passing through a meter. It is claimed for this process, that the revivification is complete, and that the quality of gas is also improved.

This process, and other modes of purification in closed vessels, a process very much desired, are being made the subject of experiment in many quarters, but as yet they appear to be still in the experimental stage.

The chemical changes which take place in the use of Oxide of iron for purification are as follows

The absorption of the H_2S is expressed by two equations

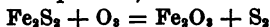


Or

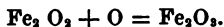


The second equation probably is nearer correct than the first.

The revivification of the spent oxide may also be expressed by two equations, thus.



Or



The second equation is here also probably the correct one. The Oxide of iron suitable for the purification of gas is hydrated oxide; in the above equations the water is omitted for the sake of simplicity.

The oxide used to a great extent at present, under the name of "Iron sponge" is a preparation obtained by treating oxide of iron in contact with carbon at a red heat with complete isolation

from the atmosphere, and consists of the non-volatile matter of the raw ore. It is light, porous and spongy and extremely sensitive to chemical action. It has taken the place to a large extent of all other oxides, the majority of the companies using it alone without lime.

The sponge weighs when in proper condition for the purifiers 40 lbs. per bushel.

It purifies from 5,000 to 15,000 cubic feet per bushel between changes, depending upon the coal used, and special conditions of the works. It purifies during its life from 60,000 to 180,000 cubic feet per bushel, depending upon the care taken to keep it free from a coating of tar or oily vapors.

To revivify it, it is spread on a floor in a well ventilated room, to the depth of 14 to 18 inches, and is ready for use again in from two to four days.

The great merit of purification by oxide of iron over purification with lime, is that the employment of the oxide is attended with less nuisance than the employment of lime for the same purpose, in a great many places the foul lime is a product very difficult to dispose of. Its use for agricultural purposes, is very small, and it is mostly used for filling in waste places.

It was stated above that the majority of companies using iron sponge dispensed with the use of lime altogether, the question naturally arises as to what becomes of the CO_2 ? This has been accounted for in this way. Lime arrests certain illuminants, and holds them, and also arrests the CO_2 . Oxide of iron allows these illuminants to pass on with the gas, and also allows the CO_2 to pass on—thus the loss of illuminants, in the lime process is balanced by the loss due to the CO_2 in the oxide of iron process, or in other words the detriment caused by the presence of CO_2 in the oxide of iron process is neutralized by the extra illuminants it allows to pass. It has been proved that there is gas in foul lime of a very fair candle power.

In a paper read before the American Gas Light Association by Mr. C. W. Blodget, of the Williamsburg, N. Y., Gas Light Co., an analysis is given of the gas purified by lime, and by oxide of iron, by which it appears as if the reasons given above for an equal candle power, by either process of purification were correct.

ANALYSIS OF GAS PURIFIED BY LIME AND "IRON SPONGE."

	Lime.	"Iron Sponge."
Hydrogen.....	48.92	47.83
Carbonic Oxide.....	6.02	5.84
Carbonic Acid.....	.00	2.19
Marsh Gas.....	36.86	36.05
Illuminants.....	5.65	6.14
Oxygen.....	.12	.09
Nitrogen....	2.43	2.36
	100.00	100.00

According to this analysis, the gas purified by the oxide of iron contains 2.19 per cent of CO₂ but to offset this, it has 5 per cent. more illuminants than the other.

ANALYSIS OF SPENT LIME.

	Water Gas.	Coal Gas.
Carbonate of Lime.....	74.27	36.00
Hydrate " "	10.86	13.10
Sulphite and Sulphate of Lime.....	9.00	44.50
Oxide of Iron and Alumina.....	2.72	2.80
Phosphate of Lime.....	.60	.40
Residue.....	3.05	3.20
	100.00	100.00

THE PURIFYING HOUSE.

The purifying house stands next in importance to the retort house, and should be placed at a respectable distance from it. It should be built with a well lighted and ventilated cellar, with all the pipes, and under side of the different apparatus easy of access. The rooms containing the purifiers, condensers and scrubbers (if in the building) should be thoroughly ventilated, and the whole lighted by lanterns in the outer walls, not accessible from the inside. No blacksmith shop or boiler house should stand nearer than 50 feet to the purifying house. The room containing the purifying boxes should not be connected by doors or windows with any of the other rooms. Warning signs against smoking should be placed near the outside door.

Iron columns should be used for the support of the floors and boxes in preference to brick piers. Iron floors are preferable to

wooden ones, especially in large works, and the spaces between the boxes should be of sufficient width to allow of a free use of barrows, and for stacking the trays while cleaning. The foul lime should be carted away from the works as soon as possible, and if not convenient to do this, it is better to pile it outside than to keep it in the building.

A purifying house, where oxide of iron is used, should have an oxide room with a floor of stone, cement or iron. This room should have the window openings unglazed, and filled in with louvres, which should extend down to floor. A good arrangement for the moving of the oxide to and from the boxes is as follows : The floor of the oxide room is made a little higher than the top of the boxes when the cover is removed, and a movable platform for barrows, extending over the boxes, has its floor on the same level, so that the oxide can be wheeled on the platforms, (which are on wheels) and dumped into any part of the boxes. Another plan is to have the oxide room below the purifiers ; in this arrangement the spent oxide is dropped through a trap in the bottom of a box into a barrow below and wheeled to the oxide room, to be brought up by an hydraulic elevator when wanted again.

The purifiers are generally arranged in sets of four, placed in a square with a center seal in the center below the floor, or in an annex at one side. A set of gate valves are sometimes used instead of a center seal, and also four-way bye-pass valves ; either of these systems admits of more changes in the using of the boxes than the ordinary center seal, but by the use of the Duplex center seal (described elsewhere) all possible changes can be made. The purifying house of the Newark Gas Light Co., built under the direction of Mr. E. Vanderpool, engineer, from plans made by Mr. Wm. Farmer, is a good example of the use of bye-pass valves. The main floor of the building is divided into lime rooms ; main purifying room, condenser room, and scrubber room. The purifying room is 138 ft. long by 42 ft. wide inside, covered with iron and slate roof, with large ventilators. This room has one main outside entrance door. The lime rooms at end are connected with the basement below by a hydraulic elevator. The purifiers, 4 in number, are placed in line, with 4 way bye-pass valves on each side opposite center of boxes.

The covers of the boxes are removed by a carriage traveling overhead the whole length of the room.



The boxes are 3 ft. 3 ins. deep, and 24 ft. by 29 ft. inside, with seven tiers of lime trays. Connections 20 inch flanged pipes throughout.

The walls are fitted with cast iron ventilated lanterns, lighted from the outside.

The floors and boxes are supported on wrought iron beams, and cast iron columns.

The basement is 12 ft. high from floor to floor, and the purifying room is 20 ft. high to lower edge of roof. The walls are 12 inches thick with pilasters—all of brick, with heavy ornamental cast iron cornice gutters.

CONDENSER ROOM.

The condenser room is 28 ft. by 32 ft. by 20 ft. high. It contains two multitubular condensers, each 19 ft. by 5 ft. by 15 ft. high. Each condenser contains four stacks of 4 in. cast iron pipes 4 ins. diam. and 11 ft. long; each stack containing 64 pipes—making 256 pipes in each condenser.

The connections are 20 ins., and one or both condensers can be used at once, or both can be bye-passed. Four way bye-pass valves are used both for condensers and scrubbers. The water connections to condensers are so arranged that a stream of cold water enters the chambers around the pipes at the outlet end and passes slowly through the four chambers in succession, entering at the bottom of chamber and passing into the next one at the top, finally leaving the last chamber at the inlet end of the condenser. The case of condenser is of cast iron—resting on granite coping and brick walls below. Each condenser contains about 3,000 square feet of cooling surface.

SCRUBBER ROOM.

The scrubber room is 23 ft. by 40 ft. and 46 ft. high from floor to underside of water tank above. It contains two Smith & Farmer Tower Scrubbers, (see description elsewhere) each 10 ft. diam. and 41 ft. high. The cases are of cast iron throughout. Each scrubber contains 50 tiers of wooden trays, separated by wooden sleepers, and each section resting on iron beams, the whole carried by brackets cast on the inside of case, and on the outside of central 20 inch outlet pipe. The water distributor is kept in motion by the water supplying it as described elsewhere under the head of Tower Scrubbers.

TANK ROOM.

The tank room over the scrubber is located in the Mansard roof, and is reached by an iron staircase from floor of scrubber room. The water tank is of wrought iron, supported by 9 inch wrought iron beams. The pump supplying tank is in the engine room located in another building.

THE EXHAUSTER.

Every gas works, however small, should have an exhauster. By its use the yield of gas per ton of coal carbonized is increased. The pressure is taken off the retorts, the amount of carbon is lessened, and consequently the life of the retorts is lengthened. The two kinds most used in this country are known as Roots' and McKenzie's—the former being rotary and a modification of the Jones' exhauster, and the latter reciprocating and a modification of the Beal's exhauster. Both of these have been improved until they are as nearly perfect as they can be made.

The improvements have been such that they are almost noiseless and need but very little attention. The steam jet is at present but very little used. Each maker claims the superiority of their machine over others, and each have their advocates, who have become such by using them. The claims made by the makers of these machines are as follows :

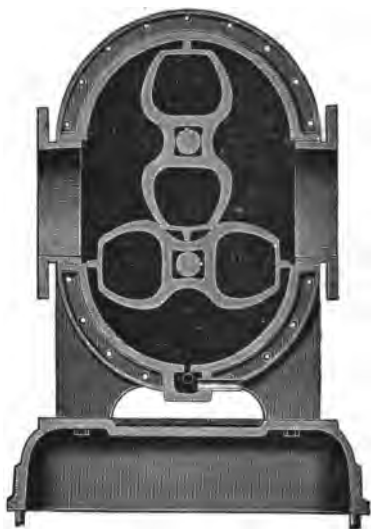
ROOTS' EXHAUSTER.

These Exhausters are made by the P. H. & F. M. Roots Co., at Connersville, Ind., and their machine is described by them as follows :

1.—The revolvers or pistons are constructed on new principles, and their form is such that they keep up a mathematically accurate contact with each other, and the case during the entire revolution ; consequently all the gas taken in at the inlet or exhaust side, is positively forced forward against any back pressure whatever in a steady, regular flow, maintaining the columns in the vacuum and pressure gauges, at a uniform height, without oscillation, and making an even steady record.

2.—The entire cylindrical parts of the case are bored out with perfect accuracy, and the adjustable packing strips used in former styles, have been given up entirely.

The internal operating parts of the exhauster require no attention whatever.



The parts requiring attention are the journals, gear wheels and stuffing boxes, all of which are external and easily accessible, and any adjustment, repairs or renewals can be made from the outside. The advantage of this method of construction need no explanation, as any repairs can be made quickly, and without any disturbance of the machine itself.

3.—A new and improved journal box, we consider far superior to any other in use. This improvement consists in a simple and perfect arrangement, by which the wear of the journal bearings is taken up all around the journals instead of from one side, thereby keeping them always in their *original central position*. The journal bearings are of phosphor bronze, and are made tapering on the outside, and with a slot at the top so that any wear on the journal bearings can be taken up by forcing them farther into the journal boxes.

4.—ARRANGEMENTS FOR OILING THE JOURNALS.—The perfect lubrication of the journals of an exhauster is of a paramount importance. An oil chamber is placed on top of the journal box, and kept filled with cotton waste well saturated with oil, which can be replaced in a moment at any time.

5.—SHAFTS.—The ends of the shafts are enlarged, which allows the shafts to be re-turned when they become worn or corroded from the use of poor coal. The shafts are also enlarged for re-turning at all the wearing places, so that the life-time of the exhauster may be prolonged indefinitely.

6.—THE OIL-TIGHT HOUSING for gear wheels, by means of which the gears are run constantly in oil is a late and most valuable improvement. In this bath of oil the gears run constantly, the oil being drawn off and replaced when necessary. The tar is drawn off from the exhauster into the trough at bottom of cylinder, from whence it runs to the tar well through a siphon pipe.

7.—No COAL TAR can, by any possibility, reach the gear wheels, as the journals and gear-housing are both outside of the stuffing boxes.

8.—PERFECT CLEANLINESS is obtained by improved methods of carrying off the drip from the stuffing boxes and journal boxes.

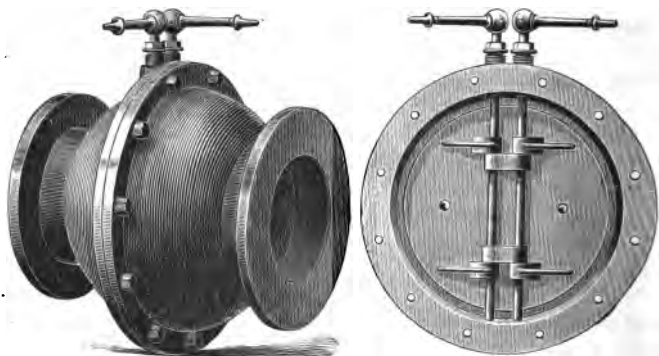
9.—DURABILITY.—The shafting is made of the best crucible steel. The journals are long and easy running, and the internal operating parts, although running so close together as to be practically gas tight, are still not in actual contact, so that internally there is no wear or friction of any kind. The gears are all cut by improved gear-cutting machines.

The arrangement of the exhauster and engine on one bed plate, thus saving shafting and belts, is a great improvement on past methods. The speeds given for these exhausters in the table below are moderate, and in time of emergency they can be run at a much higher speed with perfect safety.

SIZES, CAPACITIES, SPEED, ETC. OF ROOTS' EXHAUSTERS.

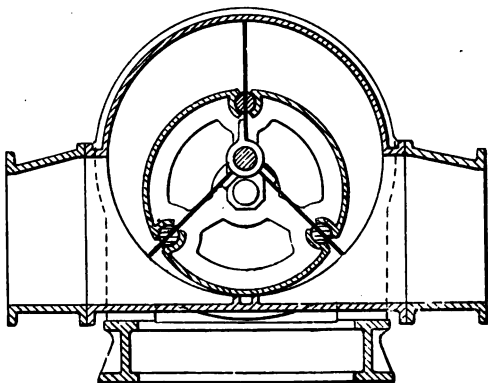
Numb'r	Diameter of Inlet and Outlet Pipes.	Horse Power Required to Run Exhauster.	Maximum Speed per Minute of Exhauster.	Capacity per Hour.
1	4 inches.	1 H. P.	Rev. per m. 165	Cb ft. 4,950
2	4 "	1 "	" " 160	" 7,200
3	6 "	2 "	" " 155	" 13,950
4	8 "	4 "	" " 150	" 27,000
5	10 "	6 "	" " 140	" 42,000
6	12 "	8 "	" " 130	" 62,400
7	16 "	10 "	" " 120	" 98,600
8	16 "	15 "	" " 110	" 158,400
9	20 "	25 "	" " 100	" 252,000
10	24 "	28 "	" " 90	" 351,000

The self-acting bye-pass valve, used in connection with the above exhausters, are made so as to be readily attached to the pipe. They have the usual flap valves and indicators on top.



THE MACKENZIE EXHAUSTER.

The Mackenzie Exhauster, manufactured by the Smith & Sayre Manufacturing Co. of N. Y., which is represented by the cut below, is well known throughout the country. Its parts consist of a cylinder or shell, enclosing flat blades revolving on a shaft and closely fitted against the interior surface of the shell.



These blades receive their motion from the small cylinder, which rotates on another shaft placed below the central one. The gas entering at right angles to the blades is swept through by them, their closeness to the surface of the shell preventing very little if any slip. This exhauster is noted for its smooth, quiet and even motion, and is very durable. It can be run by an engine direct, or by belting and shafting.

CONDENSERS.

The gas having passed through the hydraulic main, and the tar or hot condenser has parted with the heavy tar and part of the ammoniacal liquor. Condensers for taking out the remainder of the tar and liquor are either air or water condensers, with one exception, wherein the tar is extracted by impact. The gas should be cooled gradually, for a sudden cooling or too low a temperature will condense the light hydrocarbons, and diminish the illuminating power. Sudden cooling also tends to the production of Naphthaline. The temperature of the gas at the condenser outlet should not be lower than 50° Fahr. Much less cooling surface is required for a water condenser than for an air condenser. By the following table it will be seen that where the temperature of the gas is 10 degrees above the temperature of the atmosphere, a surface which would radiate 8 units of heat in the air would radiate 88 units in water.

Excess of the Temperature in the Gas.	Units of Heat Radiated by a Given Surface of Pipe.	
	When Radiating in Air.	When Immersed in Water
For an excess of 10° Fahr.	8	88
“ “ “ 20° “	18	266
“ “ “ 30° “	29	5,353
“ “ “ 40° “	40	8,944
“ “ “ 50° “	53	13,437

PERCLET.

For a small works simple air condensers are sufficient, if the gas has already passed through a tar or frictional condenser placed near the hydraulic main. The simplest form of air condenser consists of an iron box with hubs on the top, for the pipes say 16 eight inch pipes in each stack, the gas ascending four pipes and

descending four pipes alternately; the suitable divisions in the lower box controlling this. The pipes are erected in two lengths of 12 feet each, and connected by bends with hand-holes and covers at the top. Each of these pipes is filled with thin discs of cast iron, technically called butterflies, shaped like a maltese cross, and placed so that the blades in one disc shall be over the open spaces in the one below. These discs are cast very thin, with a hub in the middle, through which passes a piece of 1 inch gas pipe on which they are fastened by a pin at each end of the pipe. For convenience in handling these lengths of pipe are about 4 feet. The tendency of the discs is to divide the gas up into slow moving sinuous streams, cooling it slowly—which is the sole end and aim of a condenser.

The multitubular condenser, which is one of the oldest and best apparatus for the slow cooling of the gas, consists of a series of chambers containing pipes of cast or wrought iron, surrounded by water; so arranged that the gas and water travel in opposite directions—the hot gas at the gas inlet meeting the hot water at the water outlet; thus the water can be so regulated in its flow that the gas can be cooled to the desired temperature by regulating the flow of water. A description of a multitubular condenser, erected at the Manhattan Gas Co.'s Works, of N. Y., under the direction of the late C. V. Smith, engineer, from the plans of Mr. Wm. Farmer, will give a general idea of this style of condenser.

Details of two multitubular condensers, erected at the Manhattan Gas Light Co.'s Works, 14th Street Station, N. Y.:

Dimensions of cast iron case, 44 ft. by 6 ft. by 15 ft. high. Each condenser contains 12 stacks of 54 four inch cast iron pipes, 11 ft. long. These pipes have turned tapering joints at the bottom, and are driven into the hub plates below, the tops being cemented into socket plates above.

The condensers are divided vertically into three sections, the gas and tar chambers at the bottom, the water space surrounding the pipes, and the gas chamber above. Each stack of 54 pipes is separated from the adjoining ones by partitions made water-tight between the water spaces. Wrought iron braces extend transversely and longitudinally through the condenser to resist the water pressure. Each section or enclosed stack has a cast iron cover over the gas chamber above. The connections are 24 inch, the gas passing up one stack of pipes and down the next one,

slowly through the whole 12 stacks. The water inlet is at the base of the stack over gas outlet, and the water outlet is at the base of the stack over the gas inlet. The water passages from stack to stack are so arranged that the water flows up one stack and down the next one, entering the stacks through openings at the top and bottom of the partitions alternately.

Each stack of pipes contains 622 square feet of cooling surface, or 7,464 square feet for one condenser ; there are 594 lineal feet of 4 inch pipe in each stack, or 7,128 feet for one condenser.

The whole of the joints throughout are planed and secured with $\frac{3}{4}$ inch bolts. The tar is taken from the lower chamber or space under the pipes through the main inlet and outlet pipe, and from them by suitable pipes at a short distance from the condenser.

PELOUZE AND AUDOUIN'S CONDENSER.

This condenser is made in such a manner as to separate the gas from the tar by impact. This is done by forcing the gas through a perforated cylinder, having perforations $\frac{1}{16}$ inch diam. against an inner cylinder, having blanks opposite the perforations in the outer one. This is said to completely separate the tar from the gas, but it is a question whether the slower action of the other systems is not better ; those who have them in use speak highly of them. They are very compact, and if they do the work required of them it is certainly done at a very small expense for space.

Experience has taught the fact that too rapid condensation is injurious, and also that if the gas is kept in contact with the hot tar after leaving the hydraulic main, some of the illuminants that have been taken out by the tar can again be recovered before the tar has been allowed to cool too much. This has also been found to be a preventative to the formation of naphthaline in the pipes.

To accomplish this purpose and keep the hot gas and the hot limpid tar in close contact, several condensers have been devised. The sinuous friction condenser, made by Davis & Farnum, of Waltham, Mass., consists of a number of vertical pipes of rectangular section, and of such shape that the gas is turned to opposite sides of the pipe alternately. This condenser can also be used as an air condenser, the gas passing up and down the sinuous pipes, which rest on the usual gas and tar box at the bottom, and are connected by suitable bends at the top. The zig-zag scrubber or

condenser, invented by Mr. Wm. Farmer, has proved most successful as a tar condenser, and a preventative of the formation of naphthaline. It consists of a series of vertical chambers or gas passages, filled with wood or iron slats, placed at an angle of 45° at about 2 inches apart. The gas in its passage through these narrow zig-zag passages is brought into close contact with the hot tar. A coil of steam pipes is placed in the chamber below the slats for heating in winter, and the condenser is enclosed in brick, or protected by some heat retaining material. This apparatus can also be used with success as an air condenser. The slats are generally made of wood about 6 by $\frac{1}{2}$ inch, and unplanned. For convenience in handling they are put together in frames.

Opinions differ as to the proper amount of cooling surface required for each 1,000 cubic feet of gas. One rule for air condensers gives 6 square feet of cooling surface for every thousand feet of gas per day. Clegg gives a rule (4th edition p. 173) making $6\frac{1}{2}$ square feet of condensing surface for every 1,000 cubic feet per day of 24 hours. Another rule adopted by some gas managers is 7 square feet of surface for every 1,000 feet per day. Newbigging gives as his idea, that about 10 square feet of atmospherical condensing surface per 1,000 cubic feet per day is about the proper rule. It is probably the fact that no one rule would suit every case. The condenser should be well protected from sun and storm and kept in a room where the temperature is even throughout the year.

From Mr. Richards' work we take the following requirements for a good condenser:

"That it shall be of such length as to permit the gradual cooling of the gas."

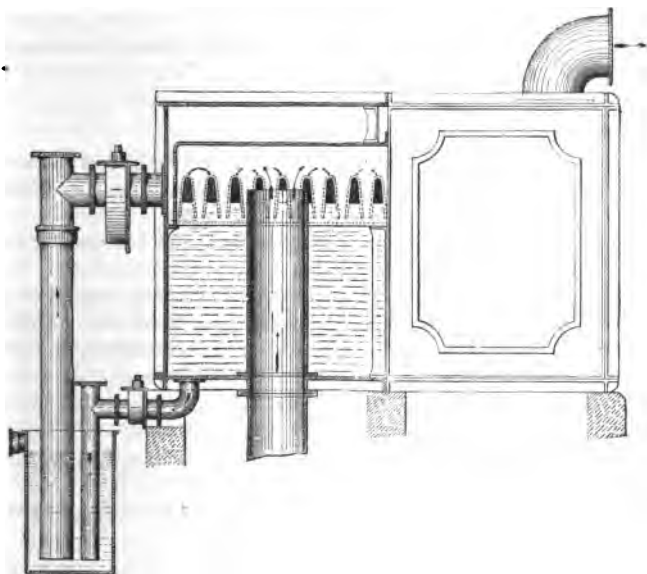
"That it shall be of comparative small sectional area, so as to produce that degree of friction, to break all the vesicules of which the tarry vapors are composed, and thus eliminate the tar before it enters the scrubber."

"That a portion of the tar shall be retained in the condenser to act as a purifying agent to eliminate the impurities for which it has an affinity."

"That the apparatus should be so placed, that its temperature shall be neither too high nor too low."

THE WALKER TAR AND CARBONIC ACID EXTRACTOR.

The Walker Tar and Carbonic Acid Extractor, an English invention, illustrated below, has been introduced into this country by Mr. Geo. Shepard Page. It comes with good endorsements from England, and if it does the work claimed for, it will prove a useful addition to our list of purifying apparatuses.



Its operation is described as follows: The gas enters into a central chamber, the only outlet from which is through one-half to three inches of concentrated ammoniacal liquor.

The gas passes through a succession of numerous tubes, reaching the whole width of the apparatus. By contact with the ammoniacal liquor, the larger portion of the tarry particles, and a considerable percentage of the carbonic acid are deposited. The frictional contact with these many tubes serves to eliminate the little remaining tar, and the gas leaves the tubes, passing into a larger upper chamber, and thence by the outlet to the washer.

As all the tar is removed, the clear water in the washer has an opportunity to deal promptly and effectually with the ammonia, which is quickly removed by the use of one quarter to one gallon of water per one thousand cubic feet.

The washer is so placed that by gravity the liquor from it runs into the tar extractor. Thus the gas is scrubbed with the best agent known for that purpose. By the use of an automatic tar gate, the tar is taken off by itself, and the concentrated liquor passes off through an overflow. The size of the tubes prevents any clogging up, and no difficulty can be experienced from back pressure, blowing out seals, etc.

TOWER SCRUBBERS.

The following is a description of the Tower Scrubbers erected at the 14th and 18th Street Stations of the Manhattan Gas Co.'s Works in 1876.

The scrubbers are of the Livesey pattern, and are erected in pairs, two at each Station.

The connections were 24 inch, and so arranged that one or both scrubbers could be used at one time, or both could be by-passed. Each scrubber was designed to pass 2,000,000 cubic feet per day, and they have been found to be of ample size to do this.

They were built upon heavy foundations, consisting of piles (8 to 12 ins. dia.) well driven, 2 ft. 6 ins. from centers. On these piles was laid a bed of concrete four feet thick, and upon the concrete bed the brick foundation walls were built. These walls were three feet thick, six feet high, and coped with heavy granite blocks, upon which the iron structure rests.

DESCRIPTION OF THE IRON STRUCTURE.

Each scrubber consists of an inner cast iron tower or scrubber proper, and an outer case or jacket principally of wrought iron.

The inner cast iron scrubber is 61 feet high by 17 feet in dia. outside measurement, and is built up in eight vertical sections of sixteen segments each.

The bottom plates are 17 ft. dia. and made in eight pieces with flanged joints.

The vertical sections vary in thickness from the lower course upwards.

On the inside of each segment of these sections, are cast iron brackets to receive the wooden beams, supporting the trays or slats of the section above. The other ends of these beams rest on supporting brackets cast on the central pipe.

The top plates are supported on iron beams extending across the top of scrubber.

The inlet and outlet box is placed under the center of each scrubber, upon a masonry foundation, and attached to the bottom plates. A vertical 24 inch pipe, 63 ft. high, cast in 9 sections with flanged joints, passes from this box to the top of scrubber, and is the outlet pipe for the gas from it.

The inlet for the gas is the annular space in the inlet box around this pipe.

The vertical pipe is braced at the top with adjustable wrought iron rods.

All the joints throughout are faced and secured with $\frac{1}{2}$ inch bolts.

The wooden trays are made of $\frac{1}{2}$ inch unplaned pine, 6 ins. wide, each slat being separated from its neighbor by a strip $\frac{1}{4}$ inch thick. They were made in sections convenient for handling and placing in position.

Each layer or tier of trays is separated from the next by strips of timber 2 by 3 ins. laid flat, and the radial points are so arranged that they do not come one over the other. This was found necessary to prevent a solid wall of wood from one beam to the next, but by shifting the joints a little to one side each time, the current of gas received a spiral motion, and the capillary attraction of the water, running down the unbroken joints was avoided.

The amount of wood surface in each scrubber is about 204,270 square feet.

The outer case or tower in which the scrubber is inclosed, is 84 feet high from base to top of ventilator, and 21 feet dia. at the base. The pedestal of the tower which is of panelled cast iron, is 16 feet high, and the wrought iron shaft above it, to the balcony is 45 feet high. Above the balcony, and at level of top of scrubber is the wheel room, about 7 feet high by 17 ft. dia.—formed by bolting upright iron posts to the top of scrubber and casing these with sheet iron.

The tops of the posts are braced and joined together by radial iron beams, which support an iron water tank, 14 feet in dia. and 3 ft. deep placed in the roof.

The water is supplied to the tank by a small pump in the main engine room of the works.

The water distributor is the invention of Mr. Wm. Farmer, and answers its purpose perfectly. It consists of an overshot wheel, 5 ft. 10 ins dia. which by proper gearing turns a vertical shaft attached to the distributing arms; these latter are two in number in each scrubber, extending from the shaft in the center to the outer edge of the trays.

The water is led from the tank above, over the top of the wheel, and falling into the buckets turns the wheel, and is then conveyed through a pipe, with a syphon bend into a cup forming a hub, to which the distributing arms are fastened, and from these falls into the arms which are kept rotating horizontally by the motion of the water wheel above, so that the same water that washes the gas, is first used as the power for keeping the distributor in motion.

The slits in the arms of the distributor which are on opposite sides, are arranged to suit the exact area of trays they are required to wet, being very close together at the outer ends, and far apart at the center.

The even and thorough manner in which this simple contrivance wets the surface of the wood slats below is remarkable—and worthy of special comment.

Before turning on the gas, this portion of the apparatus was run until the wooden trays were thoroughly saturated, the idea being to pass the gas over a succession of wet surfaces in its course through the scrubber, and not through a shower of water. This was obtained with a flow of a gallon of water per minute.

The wheel house is lighted with fifteen windows, and has an opening at the top leading to the ventilator.

Between the towers is a central stairway tower by which access is had to the balcony, and from thence to either of the wheel rooms.

The space between the outer case and the cast iron scrubber, is about 20 ins. at the base, and 15 ins. at the shaft, opening through a four inch annular space into the wheel room above.

For the purpose of controlling the temperature of the air in this space, ventilating doors and blinds are placed in the pedestal, allowing a constant current to pass up between the scrubber and outer case.

During the summer this is found efficient, keeping the temperature even with that of the atmosphere.

The space is heated in winter by steam from the heating boiler, which seems to maintain the temperature at the proper point.

The amount of water required to remove all trace of ammonia at the outlet of scrubber, was found to be $\frac{2}{10}$ gallon to 1000 cubic feet.

The strength of the liquor averaged $15\frac{62}{100}$ oz. for 6 months. All traces of tar are removed from the scrubber by the multi-tubular condenser and the zig zag dry scrubber, through which the gas passes before entering the scrubber. The surface of the wooden trays in each scrubber, measures 204,270 square feet.

THE STANDARD WASHER SCRUBBER.

This scrubber, now in extensive use in this country, consists of a series of revolving discs of metal, put together in clusters and slightly separated from each other by raised points; these clusters of discs revolve in the ammoniacal liquor extracted from the gas, and the gas passing through them, and coming in contact with the wet surfaces, the ammonia is extracted—and also any tar that may be left in it.

Various merits are claimed for this scrubber besides the extraction of the ammonia—stated by its inventor, as follows. 1st. It removes *all* the ammonia from the gas and thus increases its illuminating power. 2d. It removes one-third of the carbonic acid and sulphuretted hydrogen, thereby reducing the cost of purification. 3d. The value of the ammoniacal liquor produced by the standard will pay for its cost in a short time. 4th. But little power is needed for the revolution of the shaft. 5th. It costs less than a tower, and the expense of wood or other scrubbing materials is saved. 6th. Its capacity can be increased at any time by adding one or more sections, and lengthening the shaft.

PURIFIERS.

Purifying really does, or should commence at the Hydraulic main, but it has become the custom, to ignore the fact, in regard to the condenser and scrubber, that their mission is purification in the full sense of the word, and limit the name of purifiers to the boxes, containing the purifying material, generally lime or oxide of iron. The boxes are generally arranged in sets of four or eight, set in the form of a square, or in one line. In the first arrangement the center valve is placed either in the middle below the floor or at one side. When the boxes are arranged in line, they are generally controlled by side valves, or by 4 way bye-pass valves. In another place the methods of purification by hydrate of lime, and oxide of iron have been described, therefore it will not be necessary to enter into any description here.

The boxes are generally made about 3 ft. to 4 ft. deep, and of various sizes to suit the make of gas. When lime is used the trays are placed about 6 inches apart, and the lime placed on them about $2\frac{1}{4}$ ins. deep, the object being to have such a number of trays that any of the gas passing through interstices in the lime of one tray will pass through the lime in the next one; the back pressure is also less than when the lime is placed thicker. In using oxide of iron, or iron sponge, the material is put on the trays from 16 to 18 inches deep.

The boxes are cast iron throughout, with wrought iron covers. The joints of the cast iron boxes are planed, and the cup is cast together with the side plates. The cups should be not less than 18 inches deep and 4 inches wide—and for water gas they should be 24 inches deep. The sides of the wrought iron covers, standing as they do in water, soon corrode and become leaky at the level of the top of the water, this can be avoided entirely by having a stratum of oil on the water in the cup.

On cleaning the foul lime or spent oxide from the trays, they are struck with a light iron rod, this together with the corrosive nature of the materials, soon destroys them, if they are secured together with iron rods.

The Church tray is made to remedy this evil, and seems to be the best tray that can be used, it is made of slats of hard wood, having no cleats on the ends, but secured together compactly by ribs of malleable iron, perforated for the slats to pass through. The slats are driven tightly into the perforation in the iron ribs.

These trays are alike on both sides, and are so made that a broken slat can be replaced instantly, as extra slats are supplied with the trays. For iron purification the trays are made flat on top, and for lime they are made oval. There is no question, but that these trays have made their way on their merits, as their almost universal adoption testifies. A glance at their methods of construction, will convince any one that they will outlast any tray put together with iron bolts.



The trays rest on wrought iron bars placed about 3 ft. apart, and on ribs of ledges cast on the side plates, and around the stand pipe, or outlet pipe in purifier. The purifying material is generally removed in barrows, but in some modern works it is shot through a trap and shute in the bottom.

Many devices have been invented for removing the covers, the most common method being movable carriages, either running on a track on the floor, and sometimes on rails over head, supported on columns, resting on rim of cup or on foundations below floor. For raising the covers to a sufficient height to clear the covers of the adjoining box, long screws with suitable gearing are generally used, but late improvements have substituted the use of hydraulic jacks for this purpose. An invention of this kind has been lately patented by Jas. R. Floyd—and is now being used at the Philadelphia Gas Works and at the Consolidated Central and Equitable Works in New York City.

The apparatus now at work on boxes as large as 24 by 30 feet, the covers of which weigh 7500 lbs. each, may be briefly described as follows :

The carriage is made with strong lattice frames with four legs, with wheels running on a track in the usual manner. At each corner of the carriage are located pistons working in hydraulic cylinders.

From the tank which is secured to one of the lattice guides of carriage, the water or other liquid is forced by means of a one and one half inch compression pump, to a $2\frac{1}{4}$ inch stand pipe fixed at the center of carriage, and from thence it is distributed through a $\frac{1}{2}$ inch tube to the lower side of the piston head of each cylinder.

The cover is raised in a few minutes by one or two men, and is self lowering, the water or other liquid in the cylinders being discharged back into the tank from whence it came.

A commercial glycerine is used instead of water, on account of its low freezing point, and its value as a lubricator.

This manner of raising the covers, can be applied to old purifiers now in use.

The purifying capacity of the purifier is generally (after the retorts) the first part of a works to be over crowded, as the output of gas increases, therefore it is well to have them made at first larger than required for immediate use. It is hardly possible to have them too large, as the slower the gas moves in its passage through them the better. The above statement must not however be taken literally, as in a small works, the boxes might be too large for the force employed, to empty and fill within a reasonable time. The connections to the purifiers should be of ample size, and all bends should have hand holes for cleaning.

Rules for the dimensions of purifiers are as varied as they are numerous. Richards in his treatise gives one square yard of purifying area for each thousand feet of gas, taking the maximum consumption.

Newbigging gives—ten square yds. of trays, per ton of coal carbonized in 24 hours.

Clegg gives in his 4th Edition—3 square yards to each ton of coal carbonized. Also another rule from the same gives, "for every 150 cubic feet of gas per hour, each purifier should present one superficial foot of surface."

Hughes gives this rule. "Allow one superficial yard of seive for every 1000 cubic feet of gas per diem."

Another rule by Newbigging, which he says experience has taught him to regard with more favor than any other is: That

where 3 purifiers are in action and one idle, the maximum daily make of gas expressed in thousands multiplied by the constant .6 will give the superficial feet of each purifier.

Example—Required the superficial area of each of the 4 purifiers in a works where the maximum production is 500,000 cubic feet of gas in 24 hours.

$$500 \times .6 = 300 \text{ ft. area of purifier}$$

$$\sqrt{300} = 17.3 \text{ (say 18 feet) side of square purifier.}$$

For very small works, without exhausters, the constant .8 may be used.

If this is a little too large it is an error on the right side.

The test cocks on the cover of purifier should be convenient for use, but as near the outlet pipe as possible.

Experiments are now being made abroad, for purification in closed vessels, and also for revivifying the spent oxide *in situ*, but they have not as yet passed the experimental stage.

As before stated, both center valves, slide valves and bye-pass valves are used in making the changes in the purifiers. The center valve, although a very old device, still holds its place as a convenient and useful apparatus. As usually made they are arranged for three purifiers to be operated while one is off. A center valve for running four boxes at one time, is described elsewhere. By the use of this improved valve, fully 20 per cent. is added to the capacity of the purifiers, as the off box can be charged and put in circuit immediately.

A barrow for carting lime or oxide, possessing many advantages, was invented by Mr. W. Farmer, and is in use in many works. It consists of a body of semicircular form with a sloping front, so made that when the load is dumped, the bottom stands at an angle so that the whole load is shot over the two low front wheels. The two large wheels to which the body is hung, allow the barrow to be turned on them as on a pivot, thus suiting it to the narrow passages between the boxes.

STATION METER.

There is no more important apparatus connected with a gas works than the station meter; it is a recording accountant, telling truly day and night the production of gas, and the rate at which it is made. It is a silent sentinel with a record book, faithfully recording the history of each 24 hours. Being of such great im-

portance it should be firstly made as perfect as possible, and secondly always kept in perfect order. Station meters are always "wet meters," and care must be taken that the water line is always kept at the same level.

The station meter should be placed in a prominent position in a room with an even temperature, and so placed that the measuring drum may be drawn out for repairs by taking off the front of the meter case.

The meter case is generally made of cast-iron and cylindrical, although it is sometimes made in different ornamental or architectural forms.

The drum usually made with four partitions, dividing it into four equal compartments, is constructed of heavy tinned iron, with suitable framing and braces of wrought iron.

Recent improvements are the stationary shaft by the American Meter Co. The shaft is firmly secured at each end, thus forming a large bolt connecting the two meter heads, and allowing them to be made much lighter than when they were required to resist the pressure of the water.

The revolving drum is made with long bearings revolving on the shaft, with arrangements for their proper lubrication.

Another improvement made by Parkinson & Co. of London, and controlled by the American Meter Co., is the three partition drum, which is claimed to be better than the old four partition drum in many ways, notably in making repairs, the wider openings giving easy access to all its parts. The capacity of the meter is also increased.

The following table shows the sizes and capacity of Station Meters :

SIZE OF METER.	Hourly Cap. in Cubic Ft	SIZE OF METER.	Hourly Cap. in Cubic Ft.
2 ft. 6 ins. x 2 ft. 6 ins	833	7 ft. 6 ins. x 7 ft. 6 ins	19,800
3 " 0 " x 3 " 0 "	1,250	8 " 0 " x 8 " 0 "	21,875
3 " 6 " x 3 " 6 "	2,175	8 " 6 " x 8 " 6 "	25,000
4 " 0 " x 4 " 0 "	3,400	9 " 0 " x 9 " 0 "	28,650
4 " 6 " x 4 " 6 "	5,000	9 " 6 " x 9 " 6 "	33,300
5 " 0 " x 5 " 0 "	6,800	10 " 0 " x 10 " 0 "	36,450
5 " 6 " x 5 " 6 "	8,650	10 " 6 " x 10 " 6 "	41,700
6 " 0 " x 6 " 0 "	10,800	11 " 0 " x 11 " 0 "	46,875
6 " 6 " x 6 " 6 "	13,000	1 " 6 " x 11 " 6 "	52,000
7 " 0 " x 7 " 0 "	16,700	2 " 0 " x 12 " 0 "	62,500

THE GOVERNOR.

The Governor is a machine for controlling the pressure of the gas during its distribution through the street mains—the gas-holder giving the initial pressure, and the governor reducing it according to the quantity of gas required at certain parts of the day or night.

The duty of the governor is to keep only the required pressure of gas on the mains, and no more. Most governors require too much attention and are not in a strict sense governors, as they have to be set to any desired pressure which they will hold, but any increase or decrease in the pressure requires a change in the governor.

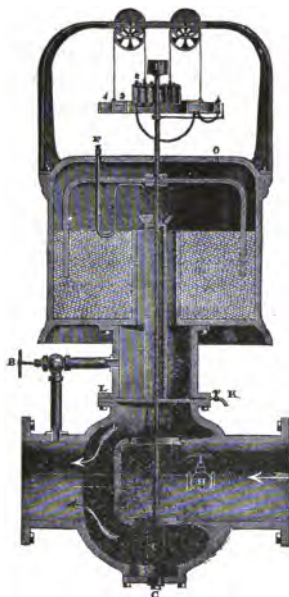
One of the greatest sources of leakage is the want of a well regulated governor, and a close study of the demands for gas and the proper hours for lighting. The hours for lighting in any community will be included in a very short space of time; the exact hour for lighting differing in different parts of the country—but the hours for turning off the gas will extend over a much longer time. The proper pressure for the time when lighting commences, and when the pressure is cut down to the regular night level should be studied carefully, and the governor adjusted accordingly. No two cities or parts of the same city will require the same pressure, as the pressure in the mains is influenced by the size of the mains, different levels of the districts lighted, and by the fluctuations of demand.

All governors have one thing in common, viz.:—The bell or small holder floating in water, and connected with the valve by a rod attached to the top; the inside of the bell being connected by a pipe with the main on the outlet side of the valve. Until a recent date all governors have been arranged with weights, operated in various ways by levers, etc., so that the pressure could be maintained at any point, until by the addition or subtraction of weights it could be raised or lowered to meet the demands of the consumers. The principal points of difference in the various governors consisted almost entirely in the manner of using the weights for adjusting the pressure. Recently, attempts have been made to produce a governor strictly automatic in its

action. A so-called automatic pressure changer, patented by Wm. Cowan, has been brought forward in England. It is not known to be in use in this country, and judging from the illustration given of it in the "London Journal," it is a very complicated and expensive affair. In this country two automatic governors have been patented, and are in successful operation.

T. C. Hopper's Automatic Differential Governor differs from all others in having no weights of any kind, the action of the governor in increasing or decreasing the pressure being accomplished by the weight and shape of the bell itself, the principle being a constant weight on varying areas. To illustrate, suppose a bell, the bottom of which has a superficial area of 1,200 square inches, and its weight on this surface to give a pressure of one inch; if this surface was reduced to 600 inches area, the pressure would be two inches, and on an area of 400 inches the pressure would be three inches. Thus it will be seen that a given weight will give different pressures by varying the diameter (or area) of the bell, and these variations can be effected either slowly or quickly, according to the curved or other lines forming the contour of the bell. By lengthening or shortening the curve between the different areas of the bell, the changes can be made slow or fast as may be desired. The valve used in connection with this governor is different from that used in others. It is so arranged that the openings can be adjusted from the outside by a center rod passing up through the bell and operated by a lever; a dial and pointer showing the extent of the opening. The valve consists of a vertical cylinder open at both ends, with vertical slots or ports on the sides, this is enclosed in another cylinder, also having vertical slots or ports made with one side at an angle. The size of the openings or ports are adjusted by moving these cylinders by the lever above mentioned.

Connelly's Automatic Governor, placed on the market in 1893, has been in successful operation since that date, and is rapidly displacing the old style of non-automatic governors. It is claimed by the makers to be strictly automatic in its action, changing the volume and pressure together at all times without any attention or manipulation whatever, thus insuring perfect distribution; the pressure being always in proportion with the volume of gas going out, and never in excess of the requirements of the consumer.



The method by which the pressure is automatically changed is novel and ingenious, and consists of the transfer of mercury from a cup attached to the bell and valve rod, to a cup connected with the valve rod by chains passing over pulleys, thus when the mercury is in the cup attached to valve rod and bell, it exerts a downward pressure opening the valve, and when the mercury is transferred to the suspended cup it exerts an upward pressure closing the valve. The transfer of the mercury is effected entirely by the rise and fall of the bell, and it is so constructed that it can be adjusted to give any two extremes of pressure desired. This is a most valuable feature, as all companies are liable to make improvements, larger mains, new holders, etc., requiring a radical change in the action of the governor. A novel design of suspension roller bearing is employed which support the weight of all the working parts and reduces the friction to a minimum and yet allows the valve to make a full stroke.

With such delicacy of construction, the governor responds to the least change in pressure, actual tests showing that the pressure or power required to operate it is but one eightieth of an inch water pressure, or in other words one-eighth of one-tenth.

The valve is double, and each plate has its outer edge ground to fit against the seats.

The action of the valves is so delicate that a steady pressure of two tenths or less can be maintained at the outlet against any inlet pressure however great.

SMITH & FARMER DUPLEX CENTER SEAL.

By the use of this invention the whole of the four boxes can be used at one time. It consists of the usual dry center valve, with the addition on the cover of a by-pass by which the gas after leaving the third box, passes up and through the by-pass into the fourth box and then back through the outlet of the center valve.

When there are four boxes in the system the following changes can be made:

1.—One of the boxes can be thrown into action alone and the remainder thrown out if required.

2.—Two of the boxes can be thrown into action alone and the remainder thrown out.

3.—Three of the boxes can be thrown into action alone and the other thrown out.

4.—Four of the boxes can be thrown into action and kept so until the paper stains, when the foul box can be taken off, cleaned and replaced immediately.

By the first arrangement the engineer is enabled to take off and keep off any of the boxes or connections which may require alteration or repairs.

By the second arrangement he is enabled to put two of the boxes in action and throw off two for making experiments or for cleaning, etc.

By the third arrangement he is enabled to put three boxes in action, and throw off one box and work in the usual way.

By the fourth arrangement he is enabled to throw every box in the system into action at once and increase the purifying capacity of his house fully 25 per cent., because every box in the system will be in action; the foulest box will be kept much longer in action than in the ordinary system, and consequently the lime will be more thoroughly utilized.

It is a well known fact that in the ordinary system of purification with three boxes on, and one off only, from 70 to 75 per cent. of the lime is thoroughly used up.

In King's Treatise it is claimed that by this system of purification 83½ per cent. is gained; the same authority also says: "When using lime purifiers for the simultaneous removal of carbonic acid, sulphuretted hydrogen and bisulphide of carbon. Mr. Patterson recommends a series of four vessels, the gas passing straight through the series. The first two deal solely with the carbonic acid, the third contains sulphide of calcium for the elimination of bisulphide of carbon, while the fourth and last arrests any sulphuretted hydrogen which escapes absorption by the previous vessels."

NAPHTHALINE.

This troublesome substance is no doubt due to high heats now used, resulting in the distillation of a portion of the coal tar. In the days of iron retorts and low heats it was unknown. It is a crystalline substance which is deposited in the mains and services in the form of flakes, which after a time are compressed into a solid mass resembling salt, but having a yellow or greenish tinge. It is soluble in naphtha but not in water. Its formation can be arrested to a great extent, if not entirely, by the use of hot scrubbers placed close to the outlet from the hydraulic main.

Naphthaline is deposited most freely from gas produced from bituminous coal. By using a proportion of cannel with the coal the gas being enriched is enabled to retain some or the whole of the naphthaline in suspension within it in the gaseous condition.

Mr. Bremond, who made experiments on the production of this substance, shows that naphthaline is produced wherever there is condensation of the aqueous vapors contained in the gas; that its deposition is preceded by the phenomenon of the condensation of water, and that gas absolutely deprived, as far as possible, of aqueous vapor does not deposit naphthaline under the ordinary conditions of temperature and pressure.

He therefore adopted means for drying the gas by passing it through unslacked lime. By this means he arrested the aqueous vapor and the excess of naphthaline. The gas increased in illuminating power by this process to a considerable extent. It has also been found that the illuminating power is increased when gas is carried through mains for a long distance—the water being deposited without any portion of the hydrocarbons being condensed with it.

Experiments made by Newbigging show that gas dried by passing it through porous chloride of calcium has a superiority in illuminating power over ordinary gas to the extent of from 6 to 8 per cent.

It has been found in actual practice that when the gas issuing from a tar scrubber was too hot and came in contact with water, naphthaline was formed very rapidly, but when the gas came from the scrubber cool no naphthaline was formed. What these temperatures were is not stated.

PRESSURE GAUGES.

Ordinary syphon or pressure gauges, when the area of the tube is the same on both sides, will give the same pressure for any area of tube.

Pressure gauges should be permanently attached to the inlet and outlet of every portion of the apparatus.

Care should be taken that the zero mark on the scale is exactly at the water level when the pressure is off.

From the pressure gauge can be ascertained the pressure in lbs. as follows :

What will be the pressure in lbs. per square inch when the pressure in the gauge is one inch.

One cubic inch of water will weigh $\frac{62.5}{1728} = 0.0361$ lbs., hence the pressure on every square inch of the surface on which the gas acts will be 0.0361 lbs.

If the pressure gauge shows a pressure of 6 inches, then the pressure on every square inch on which the gas acts, will be $0.0361 \times 6 = 0.2166$ lbs.

If the inner surface of a retort lid has an area of 240 square inches, and the gauge shows a pressure on the inside of retort of 10 inches, then the pressure of gas against the inner surface of lid will be $0.0361 \times 240 \times 10 = 86 \frac{64}{100}$ lbs.

If the pressure in lbs. per square foot when the pressure on the gauge is one inch, we have $0.0361 \times 144 = 5.1984$ lbs. or $\frac{62.5}{12} = 5.1984$ lbs. If the gauge shows 10 inches pressure we have $\frac{10}{12}$ of the weight of one cubic foot, $\frac{62.88 \times 10}{12} = 51.984$ lbs. or a pressure on every square foot of 51.984 lbs.

As the area of retort lid was 240 square inches or $\frac{240}{144} = 1 \frac{2}{3}$ square foot then the pressure on the lid will be $51.984 \times 1 \frac{2}{3} = 86.64$ lbs. when the pressure is 10 inches.

GAS MANIPULATION.

TABLE OF THE WEIGHT AND SPECIFIC GRAVITY OF GASES—
WEIGHT OF 1 CUBIC FT. AT 60° FAH. AND 30 INCHES
BAROMETRIC PRESSURE.

Name.	Symbol	Mol'cu- lar weight.	Den- sity H —1	Spec. gr Air —1	Wt. of 1 c. ft. in grains.	Wt. of 1 c. ft. in lbs.
Hydrogen	H	2.00	1.00	.0692	37.124	.00530
Carbon	C	23.94	11.97	.829	444.378	.06347
Nitrogen	N	28.06	14.03	.971	520.854	.07440
Oxygen	O	31.92	15.96	1.105	592.504	.08463
Chlorine	Cl	70.74	35.37	2.450	1313.088	.18756
Bromine	Br	159.50	79.75	5.524	2960.666	.42291
Fluorine	F	38.20	19.10	1.323	709.075	.10128
Iodine	I	253.06	126.5	8.765	4697.344	.67098
Sulphur (vapor)....	S	63.96	31.98	2.215	1187.236	.16958
Carbonic Oxide.....	CO	27.93	13.96	.967	518.441	.07405
Carbonic Acid.....	CO ₂	43.89	21.94	1.520	814.693	.11637
Sulp. Hydrogen.....	H ₂ S	33.98	16.99	1.177	630.742	.09009
Ammonia	NH ₃	17.03	8.51	.589	316.113	.04515
Sulphurous Acid....	SO ₂	63.90	31.95	2.213	1186.122	.16943
Nitrous Oxide.....	N ₂ O	44.02	22.01	1.524	817.106	.11671
Hydriodic Acid.....	HI	127.53	63.76	4.417	2367.234	.33814
Air	Mix're	28.87	14.43	1.000	535.889	.07654
Ozone	O ₃	47.88	23.94	1.658	888.756	.12695
Water vapor (Steam).	H ₂ O	17.96	8.98	.62	375.501	.04762
Hydro chloric acid gas	HCl	36.37	18.18	1.259	675.106	.05843
Hydro bromic acid...	HBr	80.75	40.37	2.797	1498.895	.21410
Hydro fluoric acid...	H.Fl.	40.20	20.10	.696	746.199	.10659
Cyanogen	C ₂ N ₂	52.00	26.00	1.801	965.233	.13787
Mercury vapor	Hg.	199.80	199.8	13.50	7417.445	1.05953
Sodium (vapor).....	Na	45.98	22.99	1.592	853.488	.12191
Potassium	K	78.08	39.04	2.704	1449.334	.20702
Bi-sulphide of carbon.	CS ₂	75.93	37.96	2.630	1409.425	.20132
Phosphorus (vapor) ..	P	123.84		4.289	1149.369	.16418
Ammonium chloride.	H ₄ NCl	53.40	13.35	.9248	486.328	.07079
Marsh gas	CH ₄	15.970	7.98	.553	296.437	.04234
Ethylene	C ₂ H ₄	27.94	13.97	.967	518.627	.07408

To find the weight of 100 cubic feet of any gas.

(1) If the specific gravity of the gas is known. Multiply the weight of 100 cubic feet of air by the specific gravity of the gas, and the product will be the weight of 100 cubic feet of gas.

EXAMPLE—Required the weight of 100 cubic feet of a gas whose specific gravity is 0.450

Weight of 100 cubic feet of air = 7.648 lbs.

$$7.648 \times 0.45 = 3.4416 \text{ lbs.}$$

Therefore 100 cubic feet of the gas weighs 3.4416 lbs.

(2) If the molecular formula is known, calculate the molecular weight, and multiply the weight of 100 cubic feet of Hydrogen by half the molecular weight of the gas. **EXAMPLE**—Benzene has the molecular formula of C_6H_6 , and its molecular weight, calculated from the atomic weight is $C = 12$, $H = 1$, $12 \times 6 = 72$, $6 \times 1 = 6$. $72 + 6 = 78$. Hence the molecular weight of C_6H_6 is 78.

The weight of 100 cubic feet of Hydrogen is 0.5307 lbs. and $0.5307 \text{ lbs.} \times \frac{78}{2} = 20.6973 \text{ lbs.} =$ the weight of 100 cubic feet of C_6H_6 .

DIFFUSION OF GASES.

If two bottles are filled with two gases of different specific gravities and connected together, one bottle being superimposed on the other (that containing the heaviest gas being the lowest), and allowed to stand for a few hours, they will be found to mix; the lighter gas finding its way to the lower bottle, and the heavy gas ascending to the bottle which is above. In this process the gases evince a positively active power of penetrating into the spaces occupied by each other and this occurs even when they are separated by membranes, or by masses of porous, earthy substances.

“ When gases of unequal densities are placed in contact with each other, they tend to mix alternately in an uniform manner, but the rapidity with which they penetrate each other's volume, or, as it is termed by Graham, the velocity of diffusion of the gases is unequal, and depends upon their densities; the lighter gases diffusing themselves most rapidly, and the heavier more slowly. Thus if a tube be closed at the top by a plug of plaster of Paris (which when dry is very porous), and filled with hydrogen gas, the lower part of the tube being sealed with water and the plug kept dry, the hydrogen and the external air tend to mix through the porous substance; but the hydrogen comes out more rapidly than the air gets in, and hence the water rises considerably in the tube. In a similar way, if a glass be filled with hydrogen gas, and the top being closed by a sheet of india-rubber, a bell glass of

air being inverted over it, the hydrogen passing out of the glass more rapidly than air enters to supply its place, the sheet of india-rubber is gradually bent into the glass, and ultimately bursts by the external pressure. On the contrary if the small glass contain air and the bell glass hydrogen, the membranous cover is gradually forced upwards by means of the excess of hydrogen which passes in and which finally breaks through it by the elasticity thus produced inside.

“The exact law of the diffusion of gases is, that the velocity of the diffusion is inversely proportional to the square roots of the specific gravity of the gases. This is exhibited in the following table :

	Specific gravities.	Specific gravities.	Diffusive volumes.
Hydrogen.....	0.0688	0.2623	457
Ammonia.....	0.5898	0.7681	130
Air.....	1.0000	1.0000	100
Carbonic Acid.....	1.5239	1.2345	81
Chlorine.....	2.4700	1.5716	64

“By this table it will be seen that in the same time in which 100 volumes of atmospheric air escape from a vessel through a membranous or porous plug, 457 volumes of hydrogen pass in; and if the vessel was previously full of hydrogen, 457 volumes will escape from it during the entrance of 100 volumes of atmospheric air. If the vessel contains carbonic acid, the result would be the passage of 81 volumes in the same time; and so of the other gases.

“This law of the passage of gases through each other, is the same as that for the passage of air into a perfectly empty space. If the different gases be allowed to strain through a porous plug into a vessel, from which the air has been removed by the air pump, they will enter with different velocities regulated by their specific gravities, precisely as in the former instance; and hence it is experimentally demonstrated that different gases are ultimately permeable to each other, precisely as the spaces they occupy would be if entirely empty; that the gases, in fact, form vacua to each other, but that so far as the law of mixture and the final effect are concerned, the mixture takes place more slowly in consequence of the mechanical obstruction.”—Kahn's Elements of Chemistry.

The importance of the action of the law of diffusion on gas stored in gasholders, and when retained in mains for any time, is considerable, as under these conditions, during a certain time, 457 volumes of hydrogen would issue from the main or holder; and be replaced by 100 volumes of atmospheric air, by these means reducing the illuminating power of the gas. Besides, according to the opinion of Dr. Frankland, to this diffusion of hydrogen, by which the carbon is deprived of its proper equivalent of that gas, is attributed the formation of naphthaline in the mains and services, which is no doubt the most reasonable theory hitherto offered for the presence of this troublesome compound.

THE EFFECTS OF ATMOSPHERIC AIR UPON THE ILLUMINATING POWER OF COAL GAS.

When coal gas is mixed with atmospheric air, its illuminating power is either destroyed or greatly impaired. The amount of loss of light must depend upon both the quality of the gas and the percentage of air in the mixture. In most books treating on this subject of gas manipulation, including King's Treatise and other standard works, tables of air and gas mixtures are given, which are entirely wrong or misleading. None of these tables agree upon the amount of light lost by the admixture of air and coal gas. Newbigging's table places the loss of light from 10 per cent. of air at 67 per cent., from 20 per cent. of air 93 per cent., and from 40 per cent. of air 100 per cent., or a total loss of illuminating power. These figures given as they are, without the candle power of the gas, are useless, for it is evident that a 60 candle gas will take a much greater percentage of air to destroy its illuminating power than a 20 candle gas.

The tables following this article give the actual loss in candles, and the percentage of loss of light by the mixture of air with gases of an illuminating power of from 14 candles to 50 candles. These calculations are based on the fact (proved by numerous experiments) that 50 per cent. of air will reduce the illuminating power of a 50 candle gas to zero.

Air is taken as a negative illuminant the value of which is —50.

In testing the candle power of rich gas, and for other experimental purposes, air and gas mixtures may be used as follows :

(1.)—For determining the percentage of atmospheric air required to reduce the illuminating power of any gas of a known candle power to any lower candle power required.

(2.)—For determining the percentage of atmospheric air in an air and gas mixture when the candle power of both mixture and gas is known.

(3.)—For determining the illuminating power of very rich gases.

1.—To find the percentage of atmospheric air required to reduce the candle power of any gas to a required lower candle power.

EXAMPLE.—A certain gas has an illuminating power of 30 candles, how much atmospheric air must be added to reduce it to 20 candle power?

Let x = the percentage of gas—

“ y = “ “ “ air—and $x + y = 100$.

$$\begin{array}{rcl} x \times 30 & = & 30x \\ y \times -50 & = & -50y \\ \hline x + y & & 30x - 50y \end{array}$$

Then $x + y = 100$ and $x = 100 - y$.

$$\frac{30x - 50y}{100} = 20 \text{ candles} = \text{value of the mixture.}$$

$$30x - 50y = 2,000$$

$$x = \frac{2,000 + 50y}{30}$$

$$100 - y = \frac{2,000 + 50y}{30}$$

$$8,000 - 30y = 2,000 + 50y$$

$$8,000 - 2,000 = 50y + 30y$$

$$1,000 = 80y$$

$$y = \frac{1,000}{80} = 12.5 \text{ per cent. of air.}$$

PROOF. Percentage of gas = $100 - 12.5 = 87.5$ per cent.

$$\text{Gas } 87.5 \times 30 = 2,625.0$$

$$\text{Air } 12.5 \times -50 = -625.0$$

$$\begin{array}{r} 100 \\ 2,000 \end{array}$$

$$\frac{2,000}{100} = 20 \text{ candles} = \text{value of mixture.}$$

From the above we obtain the following rule—

To find the percentage of air required to reduce the candle power of a gas to a required lower candle power.

RULE.—Multiply the candle power of the gas by 100 and from the product take the required candle power, multiplied by 100. Divide this difference by the sum of the candle power of the gas and the constant 50. The quotient will be the required percentage of air.

EXAMPLE.—If a gas has a candle power of 40 candles, what percentage of air is required to reduce it to 20 candle power?

$$\frac{(40 \times 100) - (20 \times 100)}{40 + 50} = 22 \frac{2}{3} \text{ per cent. of air.}$$

PROOF. Percentage of gas = $100 - 22.22 = 77.78$.

$$\text{Gas } 77.78 \times 40 = 3,111.2$$

$$\text{Air } 22.22 \times -50 = -1,111.0$$

$$\begin{array}{r} 100 \\ 2,000.2 \end{array}$$

$$\frac{2,000.2}{100} = 20 \text{ candles.}$$

2.—To find the percentage of atmospheric air in an air and gas mixture, when the candle power of both mixture and gas are known.

EXAMPLE.—What is the percentage of air in an air and gas mixture of 15 candle power, the illuminating power of the gas being 20 candles?

Let x = the percentage of gas—

“ y = “ “ “ air—

Then $x + y = 100$ and $x = 100 - y$.

$$\begin{array}{rcl}
 x \times 20 & = & 20x \\
 y \times -50 & = & -50y \\
 \hline
 x + y = 100 & & 20x - 50y \\
 20x - 50y & & \\
 \hline
 100 & & \\
 1,500 + 50y & & \\
 x = \frac{\quad}{20} & = & 15 \text{ candles, value of mixture.}
 \end{array}$$

Substituting value of x we have

$$\begin{array}{rcl}
 100 - y & = & \frac{1,500 + 50y}{20} \\
 2,000 - 20y & = & 1,500 + 50y \\
 2,000 - 1,500 & = & 20y + 50y \\
 500 & = & 70y \\
 y & = & \frac{500}{70} = 7.14 \text{ per cent. of air.}
 \end{array}$$

PROOF. Gas = $100 - 7.14 = 92.86$

$$\begin{array}{rcl}
 \text{Gas } 92.86 \times 20 & = & 1,857.2 \\
 \text{Air } 7.14 \times -50 & = & -357.0 \\
 \hline
 100 & & 1,500.2
 \end{array}$$

$$\frac{1,500.2}{100} = 15 \text{ candles.}$$

From the above we obtain the following rule—

To find the percentage of air in a mixture when the candle power of both mixture and gas is known.

RULE—From the product of the candle power of the gas multiplied by 100, take the product of the candle power of the mixture multiplied by 100—Divide this difference by the sum of the candle power of the gas added to the constant 50. The quotient will be the percentage of air in the mixture.

EXAMPLE.—What percentage of air has been added to a 30 candle gas, the illuminating power of the mixture being 20 candles?

$$\frac{(30 \times 100) - (20 \times 100)}{30 \times 50} = 12.5 \text{ per cent. of air.}$$

PROOF. Percentage of gas = $100 - 12.5 = 87.5$

$$\text{Gas } 87.5 \times 30 = 2,625.0$$

$$\text{Air } 12.5 \times -50 = -625.0$$

$$100$$

$$2,000$$

$$\frac{2,000}{100} = 20 \text{ candles.}$$

3.—To determine the illuminating power of very rich gases—

To a measured volume of the rich gas add a measured volume of atmospheric air so that the illuminating power of the mixture can be consumed in the burner with a perfect combustion.

When the candle power of the mixture is obtained

RULE.—Multiply the percentage of air in the mixture by 100, divide the product by the percentage of the rich gas in the mixture and the quotient will give the candle power of the rich gas.

EXAMPLE.—If the mixture contains 60 per cent. of rich gas, and 40 per cent. of air, and the illuminating power of the mixture is 20 candles, what will be the illuminating power of the rich gas?

$$40 \times 100$$

$$\text{ANSWER—} \frac{40 \times 100}{60} = 66 \frac{2}{3} \text{ candles—}$$

Or multiply the candle power of the mixture by 100, and the percentage of air in the mixture by the constant 50; add the two products together. Divide the sum by the percentage of rich gas in the mixture, and the quotient will be the candle power of the rich gas.

EXAMPLE.—Question as before.

$$(20 \times 100) + (40 \times 50)$$

$$\text{ANSWER—} \frac{(20 \times 100) + (40 \times 50)}{60} = 66 \frac{2}{3} \text{ candles.}$$

GAS MIXTURES.

1.—To find the number of cubic feet of each of two gases of known candle power to produce 1,000 cubic feet of gas of a desired candle power.

Let a = a gas of 15 candles—

" b = " " " 40 " —

" c = the desired candle power say 20

" x = the required quantity of one of the gases, say a .

1,000 cubic feet = the volume of gas in the mixture.

FORMULA.

$$a x + b (1,000 - x) = c 1,000$$

Substituting the value of the letters we have—

$$15 x + 40 (1,000 - x) = 20,000$$

$$15 x - 40 x + 40,000 = 20,000$$

$$-25 x = -40,000 + 20,000$$

$$-x = -20,000$$

$$25$$

x = 800 cubic feet of 15 candle gas

then $1,000 - 800 = 200$ cubic feet of 40 candle gas.

PROOF.— $800 \times 15 = 12,000$

$200 \times 40 = 8,000$

1,000

20,000

20,000

$\frac{20,000}{1,000} = 20$ candles = candle power of mixture.

Or the same results may be obtained by substituting the letters x and y for the number of cubic feet of each of the gases,

Then we have

x = the 15 candle gas.

y = " 40 " "

then $x \times 15 = 15 x$

$y \times 40 = 40 y$

$x + y$

$15 x + 40 y$

$$\begin{array}{rcl} x + y = 1,000 & 15x + 40y & \\ x = 1,000 - y & \frac{1,000}{1,000} & = 20\text{-candle power of mixture.} \end{array}$$

$$\begin{array}{r} 15x + 40y = 20,000 \\ 15x = 20,000 - 40y \\ x = 20,000 - 40y \\ \hline 15 \end{array}$$

$$\text{Substituting value of } x \quad 1,000 - y = \frac{20,000 - 40y}{15}$$

we have—

$$\begin{array}{r} 15,000 - 15y = 20,000 - 40y \\ 40y - 15y = 20,000 - 15,000 \\ 25y = 5,000 \end{array}$$

$y = 200$ cubic feet of 40 candle gas

$x = 1,000 - y$ and $1,000 - 200 = 800$ cubic feet of 15 candle gas.

From the above we obtain the following rule—

To find the number of cubic feet of each of two gases of known candle power, to produce 1,000 cubic feet of a desired candle power.

RULE.—Multiply the required candle power by 1,000 and from the product subtract the candle power of the poorer gas multiplied by 1,000 ; divide this difference by the difference of the two candle powers and the quotient will give the number of cubic feet of the richer gas.

EXAMPLE. In 1,000 cubic feet of a gas mixture of 30 candle power, how many cubic feet each of two gases of 18 and 40 candle power will be required ?

$$\begin{array}{rcl} 30 \times 1,000 = 30,000 & 12,000 & \\ 18 \times 1,000 = 18,000 & \frac{12,000}{40-18} & = 545 \frac{4}{5} \text{ cubic feet of 40} \\ & & \text{candle gas.} \end{array}$$

$$1,000 - 545.4 = 454.6 \text{ of 18 candle gas.}$$

$$\begin{array}{rcl} \text{PROOF.} & 545.4 \times 40 = 21,816.0 \\ & 454.6 \times 18 = 8,182.8 \\ & \hline & 1,000 & 29,998.8 \end{array}$$

$$\frac{29,998.8}{1,000} = 30 \text{ candles.}$$

2.—To find the quantity of rich gas necessary to be added to a given quantity of poor gas to raise it to a desired candle power.

EXAMPLE.—To 500 cubic feet of 16 candle gas how many cubic feet of 30 candle gas must be added to raise it to a 20 candle gas?

Let x = the number of cubic feet of 30 candle gas required.

$$\text{Then } 500 \times 16 = 8,000$$

$$x \times 30 = 30x$$

$$\begin{array}{r} 500 + x \end{array} \quad \begin{array}{r} 8,000 + 30x \end{array}$$

$$\frac{8,000 + 30x}{500 + x} = 20 \text{ desired candle power.}$$

$$30x + 8,000 = 10,000 + 20x$$

$$30x - 20x = 10,000 - 8,000$$

$$10x = 2,000$$

$$x = 200 \text{ cubic feet of 30 candle gas.}$$

$$\text{PROOF.} \quad 500 \times 16 = 8,000$$

$$200 \times 30 = 6,000$$

$$\begin{array}{r} 700 \end{array} \quad \begin{array}{r} 14,000 \end{array}$$

$$\frac{14,000}{700} = 20 \text{ candles.}$$

From these figures we obtain the following rule—

To find the quantity of rich gas to be added to a given quantity of poor gas to raise it to a desired candle power.

RULE.—Multiply the required candle power by the given volume of gas; from the product take the product of the given volume of gas by its candle power; divide this difference by the difference between the candle power of the rich gas and the required candle power and the quotient will be the number of cubic feet required.

EXAMPLE.—Question as before.

$$500 \times 20 = 10,000$$

$$500 \times 16 = 8,000$$

$$\begin{array}{r} 2,000 \end{array}$$

$$\frac{2,000}{30 - 20} = 200 \text{ cubic feet of 30 candle gas.}$$

3.—In a gas mixture of known candle power, the candle power and percentage of one of the gases also being known, to find the candle power of the other gas.

EXAMPLE.—A mixture of gases consists of 90 per cent. of a 14 candle gas, and 10 per cent. of a gas of unknown candle power. The illuminating power of the mixture is found to be 20 candles—Required the candle power of the unknown gas.

Let x = the candle power of the unknown gas.

$$90 \times 14 = 1,260$$

$$10 \times x = 10x$$

$$\begin{array}{r} 100 \\ 1,260 + 10x \end{array}$$

$$\frac{1,260 + 10x}{100} = 20 \text{ candles—value of mixture.}$$

$$1,260 + 10x = 2,000$$

$$10x = 2,000 - 1,260$$

$$x = 74 \text{ candles} = \text{value of rich gas.}$$

PROOF. —	$90 \times 14 = 1,260$	$2,000$	
	$10 \times 74 = 740$	$\frac{2,000}{100} = 20 \text{ candles.}$	
	100	$2,000$	

From the above figures we obtain the following—

To find the candle power of one of the gases in a mixture, when the candle power of the mixture, and the candle power and percentage of the other gas are known.

RULE.—Multiply the illuminating power of the mixture by 100; from the product take the product of the candle power of the one gas multiplied by its percentage, and divide the difference by the percentage of the gas of unknown candle power. The quotient will be the candle power of the gas of unknown candle power.

EXAMPLE.—If 80 per cent. of a gas of 15 candle power is added to 20 per cent. of a gas of unknown candle power, the illuminating power of the mixture being 20 candles, what is the candle power of the unknown gas?

$$\frac{(20 \times 100) - (15 \times 80)}{20} = 40 \text{ candles, the candle power of unknown gas.}$$

PROOF. —	$80 \times 15 = 1,200$	$2,000$	
	$20 \times 40 = 800$	$\frac{2,000}{100} = 20 \text{ candles.}$	
	100	$2,000$	

LETHEBY'S PHOTOMETER.—SIMPLE RATIO.

10 OBSERVATIONS.

10 minutes—duration of test.

2 candles—standard of comparison.

5 cubic feet per hour—standard gas consumption.

40 grains in 10 minutes—standard sperm consumption.

Let a = actual consumption of sperm in 10 minutes.

" b = sum of observations of candle power.

" c = actual consumption of gas per hour.

" x = corrected candle power.

" y = real candle power.

CORRECTION FOR SPERM.

$$40 : a = \frac{2b}{10} : x$$

$$x = \frac{ab}{200}$$

CORRECTION FOR GAS.

$$c : 5 = \frac{ab}{200} : y$$

$$y = \frac{ab}{40c}$$

RULE.—Multiply the sum of the 10 observations of the candle power by the grains of sperm consumed in the 10 minutes for a dividend; multiply the number of cubic feet of gas consumed per hour by the constant 40 for a divisor. The quotient will be the candle power.

EXAMPLE.—If the sum of the 10 observations be 100, the consumption of sperm in the 10 minutes 40 grains; the consumption of gas per hour 5 cubic feet, what will be the candle power?

$$\text{ANSWER.}— \frac{100 \times 40}{5 \times 40} = 20 \text{ candles.}$$

LETHEBY'S PHOTOMETER.—"FARMER'S THEOREM."

SQUARING GAS ONLY.

Symbols have same value as before.

CORRECTION FOR SPERM.

$$40 : a = \frac{2b}{10} : x$$

$$x = \frac{ab}{200}$$

CORRECTION FOR GAS.

$$c^2 : 5^2 = \frac{ab}{200} : y$$

$$y = \frac{ab}{8c^2}$$

RULE.—Multiply the sum of the 10 observations of the candle power by the grains of sperm consumed in the 10 minutes for a dividend ; multiply the square of the number of cubic feet of gas consumed per hour by the constant 8 for a divisor ; the quotient will be the candle power.

EXAMPLE.—If the sum of the 10 observations be 100 ; the consumption of sperm in the 10 minutes 40 grains ; the consumption of gas per hour 5 cubic feet ; what will be the candle power

$$\text{ANSWER.}—\frac{100 \times 40}{5^2 \times 8} = 20 \text{ candles.}$$

ILLUMINATING POWER.

For testing the illuminating power of gas the Letheby-Bunsen Photometer is generally used, for an approximate determination of the candle power, a jet photometer is also used.

The standard candle used in the bar photometer is a sperm candle, six of which weigh one pound, and each burns 120 grains of sperm per hour.

The gas is supplied through an experimental meter, and burns at one end of a graduated bar, and the candles (two of which are used) at the other. The candles are arranged to burn without removing them from the scales.

The disc is contained within a sliding box or carriage which also has two mirrors, placed at the proper angle, so that both sides of the disc can be seen at once.

The bar is graduated in accordance with the law, that lights which equally illuminate an object are to each other as the square of their distance from that object.

The other apparatus required are, a governor to regulate the pressure of the gas; a minute clock or a stop watch; a King's pressure gauge, a candle balance and weights; a thermometer and a barometer, but the two latter are not absolutely necessary.

The room should be ventilated and daylight excluded, and the walls painted a dead black.

The gas should be lighted 15 minutes before the tests are made, and kept burning continuously to the end of the same.

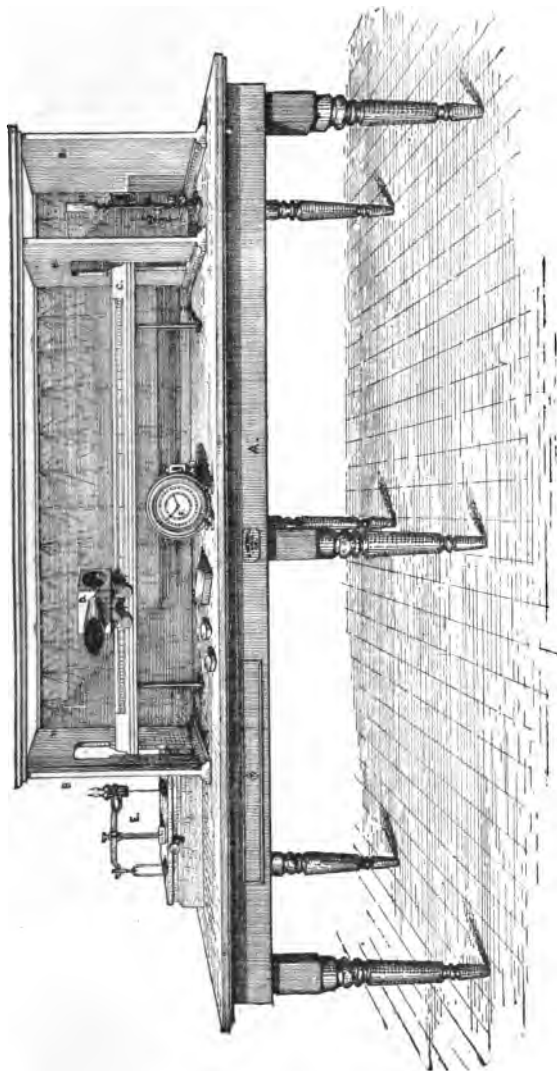
Each testing should include 10 observations occupying 10 minutes. The consumption of gas to be carefully adjusted to 5 cubic feet per hour.

The candles should be lighted at least 10 minutes before beginning the test, the standard consumption for the candles should be 120 grains each per hour.

To meet the requirements of small companies, who wish to test the power of their gas, and cannot afford an expensive outfit, various illuminating power meters, and jet photometers have been invented; and while some of them may give an approximate test, none are yet able to compete with the bar photometer. At the same time, a jet photometer gives to the gas manager a ready means of noting the uniformity of the quality of the gas, at all times.

In answer to many inquiries for a photometric apparatus, for small works, The American Meter Co. have arranged a simplified photometrical outfit, which is expected to answer the purpose, and give as exact results, as a more expensive one. The list of items contained in this outfit is as follows :

- 1 Table with drawer.
 - 1 Set of screens with black curtains.
 - 1 Sixty inch graduated bar, supported on brass standards.
 - 1 Travelling sighting box, with mirrors and disc, and fitted with trumpet tube, complete.
 - 1 Candle balance, 2 candles to weigh in place.
 - 1 King's experimental meter.
 - 1 Set of grain weights $\frac{1}{2}$ to 30 grains, (in case).
 - 1 Gas pillar with micrometer cock, syphon and pressure gauge.
 - 1 Double dry governor.
 - 1 Stop watch.
 - 1 Box, and two lbs. Standard candles.
 - 1 " each of shot and sand.
 - 1 Argand burner.
 - 1 Flat flame burner.
 - Connections from meter to double governor.
 - " " Double governor to gas pillar.
- All the necessary parts are painted black.



PHOTOMETRICAL APPARATUS.
AMERICAN METER CO.

ILLUMINATING POWER OF OLD GAS.

From experiments made in England, 120,000 cubic feet of gas was kept in a holder 6 months. The candle power when first tested was 15½, when tested at the end of 6 months, it was 14½.

CANDLE FEET.

In the American Gas Light Journal of June 1876 there was published under the above title, an article by Wm. Farmer, adding to the vocabulary of Gas Lighting a new word, viz., Candle feet. This was used to express in one term the yield and candle power, of coal, or in other words it expressed the light giving power of one pound of coal. A similar compound word is used in mechanics viz., "foot pounds." By multiplying the yield per pound of coal by the candle power, they are brought together in one simple term, and by the use of it, one gas can be easily compared with another, much more simply than by the formula for sperm equivalent or any other, for example:

If one pound of Penn. coal will yield 4.25 cubic ft. of 15.75 candle gas, and one pound of Despard coal will yield 4.25 cubic ft. of 20 candle gas, what is the value of each in candle feet, and which is the most valuable for gas making purposes, other things being equal?

Penn. coal $4.25 \times 15.75 = 66.93$ candle feet.

Despard " $4.25 \times 20.00 = 85.00$ " "

and $(85.00 - 66.93) \times 100 = 26.99$ per cent.

66.93

The Despard coal is therefore worth 26.99 per cent. more for gas making purposes, than the Penn. coal. It may be said in favor of the Penn. coal that it yields more coke per ton, and requires less lime for purification, but their qualities are aside from the object of this article.

Another comparison may be shown thus.

If one pound of coal A yields 5 cubic ft. of 13.60 candle gas, and one " " " B " 4.25 " " " 16.00 " " " other things being equal, what is the value of each?

Coal A $5 \times 13.60 = 68$ candle feet.

" B $4.25 \times 16.00 = 68$ " "

The two coals are therefore of equal value for gas making purposes.

It is a fact generally understood that there is more light in a pound of coal than is obtained from it, the use of candle feet in calculations, will prove this to be true.

To find what the total yield will be from any oil or coal.

RULE—Multiply the yield of gas by its candle power and the product will give the yield in candle feet.

EXAMPLE—If a pound of coal yields 5 cubic feet of 15 candle gas it will yield $5 \times 15 = 75$ candle feet.

To find which coal of two or more samples, gives the greatest yield.

EXAMPLE—If one sample of coal yields 4.75 cubic feet of 16 candle gas, and another sample yields 5 cubic feet of 15 candle gas, which is the better coal for illuminating purposes?

The first sample yielded $4.75 \times 16 = 76$ candle feet.

“second “ “ $5.00 \times 15 = 75$ “ “

Therefore the first sample yielded 1 candle foot or $1\frac{1}{100}$ per cent. more than the second sample, and consequently it will be the better gas for illuminating purposes.

EFFECTS OF CARBONIC ACID ON ILLUMINATING POWER OF GAS.

EXPERIMENTS MADE BY J. T. SHEARD, F. C. S. THE SAME QUALITY OF GAS USED IN ALL THE TESTS.

SUGG'S "D" ARGAND BURNER

Averages and Number of Tests	CO ₂ in Gas per centage by Volume.	ILLUMINATING POWER OF GAS.					
		Bunsen Photometer.			Mean of Lowe's Jet and Sugg's illuminating power meter.		
		CO ₂ Present.	CO ₂ Absent	Diff'ren'e	CO ₂ Present	CO ₂ Absent	Diff'ren'e
10		Candles.	Candles.	Candles.	Candles.	Candles.	Candles.
Average 10	2.68	21.60	23.16	1.56	20.33	21.34	1.01
Average 5	1.06	22.11	22.80	0.69	21.23	21.51	0.28
Average 5	2.65	SUGG'S STEATITE FLAT-FLAME BURNER. NO. 2.					
		16.52	19.11	2.59	20.09	21.17	1.08
Average 5	2.62	BRAY'S REGULATOR UNION-JET BURNER. NO. 3.					
		12.57	15.17	2.60	20.13	21.20	1.07
Average 5	1.05	SUGG'S STEATITE FLAT-FLAME BURNER. NO. 3.					
		18.56	19.70	1.14	20.67	21.08	0.41
Average 5	1.09	BRAY'S REGULATOR UNION JET BURNER. NO. 3.					
		14.72	15.85	1.13	20.81	21.22	0.41

SPECIFIC GRAVITY OF THE GAS. (Air = 1,000.)

		CO ₂ Present.	CO ₂ Absent.
Aug. 10.....		527	500
" 11.....		516	503
" 15.....		509	495
" 17.....		518	492
" 18 (three tests)....		516	493
Average.....		516	496

The above tests were made in 1887, from Aug. 10th to Aug. 26th. The illuminating power was tested with sperm candles, a different pair being used for nearly every test, and an average obtained from the result of 10 experiments. In each complete experiment, (consisting in the testing of the illuminating power of the gas, before and after the removal of carbonic acid) the same candles were used.

SUMMARY OF RESULTS.

The full amount of CO₂ originally contained in the gas under examination, 2½ per cent. destroyed the illuminating power of 23 candle gas, to the extent of 1½ candles, when the gas was burned in an Argand burner, and of rather less than 2½ candles when flat flame burners were used; that 1 per cent. caused a similar loss of two-thirds of a candle with an Argand, and of rather more than 1 candle with flat flame burners; that the actual loss of illuminating power, when flat flame burners are employed, is practically the same with an equal amount of impurity, whether the illuminating power developed be high or low. The percentage loss of light *increases* as the duty of the burner *decreases*; and the effect of CO₂ in destroying the illuminating power of coal gas, increases in equal proportion with the amount of the impurity contained.

Experiments made by C. W. Hinman, Gas Inspector for the State of Mass.

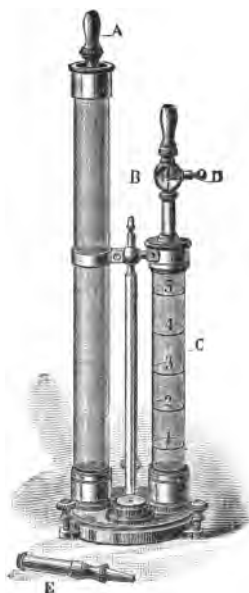
ARGAND BURNER.

CO ₂ in Gas.	Loss of Light	Ratio.
1.8 per cent.	2.3 per cent.	1.8
2.8 " "	5.4 " "	1.9
4.9 " "	9.2 " "	1.9
7.5 " "	15.1 " "	2.0

SLIT BURNER.

1.4 per cent.	6.3 per cent.	4.5
2.5 " "	12.4 " "	5.0
3.9 " "	16.9 " "	4.3

Illuminating power of gas about 19 candles.



SPECIFIC GRAVITY TEST.

(AMERICAN METER CO.)—N. Y. AND PHILA.

This apparatus for testing the specific gravity of gas by effusion is as accurate as it is simple. It consists of two vertical glass tubes, connected at the bottom; the shorter tube having a scale marked upon it, and is fitted with a 8 way cock at the top. The tubes are filled with water until it stands a little above the figure 5 on the graduated tube. The water in the graduated tube is then drawn down, to a point a little below the figure 1. The cock B is then closed, and the tube E being in position above, the cock B is opened allowing the air to pass up through the orifice in the tube E, and the time occupied by the water in rising from 1 to 5 is noted by a stop watch. A gas connection is then made at the nipple D by means of a rubber tube, the graduated tube is filled

with gas, so that the water stands as before below the fig. 1, and the same process gone over as before. The specific gravity is determined by dividing the square of the gas time by the square of the air time. Tables are supplied with the apparatus, by which the sp. gr. can be calculated quickly.

GAS COMPARED WITH OTHER ORDINARY LIGHT GIVING MATERIALS.

(DR. LETHEBY).

5 Cubic feet of common gas (at \$1.00 per 1000 cubic feet) gives a light equal to

25 Argand lamps, burning the best sperm oil at the rate of 133 grains per hour (price of sperm \$2.00 per gallon); or

23 mould tallow candles of six to the pound, each burning at the rate of 145 grains per hour (price 12½ cts. per lb.), or

18 common oil lamps burning the best sperm oil at the rate of 133 grains per hour (price of sperm \$2.00 per gallon); or

13 sperm candles, six to the pound, each burning at the rate of 133 grains per hour (price 50 cts. per lb.); or

15 composition candles, six to the pound, each burning at the rate of 136 grains per hour (price 50 cts. per lb.) or;

16.25 wax candles, six to the pound (50 cts. per lb.)

ESTIMATING THE COST OF GAS, AND OTHER LIGHT GIVING MATERIALS AT THE PRICE AFFIXED ABOVE WE HAVE THE RELATIVE COST OF THE VARIOUS ILLUMINATING AGENTS.

Gas	equal to 1
Sperm oil burnt in Argands.....	" " 8
Mould tallow candles, six to the pound.....	" " 12
Sperm oil burnt in an open lamp.....	" " 17
Sperm candles, six to the pound.....	" " 24
Composition candles, six to the pound.....	" " 29
Wax candles, six to the pound	" " 30

In other words \$1 00 worth of gas will go as far in the production of light as \$8 worth of sperm oil burnt in an Argand lamp, or \$12.00 worth of mould candles, &c., &c., &c.

PHOTOMETER TABLE

CALCULATED FOR ONE CANDLE. (SUGG.)

Con- sumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	110	111	112	113	114	115	116	117	118
4.5	1.01851	1.02777	1.03703	1.04629	1.05555	1.06481	1.07407	1.08333	1.09259
4.6	.99637	1.00543	1.01449	1.02355	1.03260	1.04166	1.05072	1.05978	1.06884
4.7	.97517	.98404	.99290	1.00177	1.01063	1.01950	1.02836	1.03723	1.04609
4.8	.95486	.96354	.97222	.98090	.98958	.99826	1.00694	1.01562	1.02430
4.9	.93537	.94387	.95238	.96088	.96938	.97789	.98639	.99489	1.00340
5.0	.91666	.92500	.93333	.94166	.95000	.95833	.96666	.97499	.98333
5.1	.89869	.90688	.91508	.92320	.93137	.93954	.94771	.95588	.96405
5.2	.88141	.88942	.89743	.90544	.91346	.92147	.92948	.93750	.94551
5.3	.86477	.87264	.88050	.88836	.89622	.90408	.91194	.91981	.92767
5.4	.84876	.85648	.86419	.87191	.87962	.88734	.89506	.90277	.91049
5.5	.83333	.84090	.84848	.85606	.86363	.87121	.87878	.88636	.89393

Con- sumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	119	120	121	122	123	124	125	126	127
4.5	1.10185	1.11111	1.12037	1.12962	1.13888	1.14814	1.15740	1.16666	1.17592
4.6	1.07789	1.08695	1.09601	1.10507	1.11413	1.12318	1.13224	1.14130	1.15036
4.7	1.05496	1.06383	1.07269	1.08156	1.09042	1.09928	1.10815	1.11702	1.12588
4.8	1.03298	1.04166	1.05034	1.05902	1.06770	1.07638	1.08506	1.09375	1.10243
4.9	1.01190	1.02040	1.02891	1.03741	1.04591	1.05442	1.06292	1.07142	1.07993
5.0	.99166	1.00000	1.00833	1.01666	1.02499	1.03333	1.04166	1.04999	1.05833
5.1	.97222	.98039	.98856	.99673	1.00490	1.01307	1.02124	1.02941	1.03758
5.2	.95352	.96153	.96955	.97756	.98557	.99358	1.00160	1.00961	1.01762
5.3	.93553	.94339	.95125	.95911	.96698	.97484	.98270	.99056	.99842
5.4	.91820	.92592	.93364	.94135	.94907	.95679	.96450	.97222	.97993
5.5	.90151	.90909	.91666	.92424	.93181	.93939	.94696	.95454	.96212

Con- sumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.							
	128	129	130	131	132	133	134	135
4.5	1.18518	1.19441	1.20370	1.21296	1.22222	1.23148	1.24074	1.25000
4.6	1.15942	1.16847	1.17753	1.18659	1.19565	1.20471	1.21376	1.22282
4.7	1.13475	1.14361	1.15248	1.16134	1.17021	1.17907	1.18794	1.19680
4.8	1.11111	1.11979	1.12847	1.13715	1.14583	1.15451	1.16319	1.17187
4.9	1.08843	1.09693	1.10544	1.11394	1.12244	1.13095	1.13945	1.14795
5.0	1.06666	1.07500	1.08333	1.09166	1.10000	1.10833	1.11666	1.12500
5.1	1.04575	1.05392	1.06209	1.07026	1.07843	1.08660	1.09477	1.10294
5.2	1.02564	1.03365	1.04166	1.04967	1.05769	1.06570	1.07371	1.08173
5.3	1.00628	1.01415	1.02201	1.02987	1.03773	1.04559	1.05345	1.06132
5.4	.98765	.99537	1.00308	1.01080	1.01851	1.02623	1.03395	1.04168
5.5	.96969	.97727	.98484	.99242	1.00000	1.00757	1.01515	1.02272

RULE—Multiply the number standing beneath the number of grains consumed by the candle, and opposite the number of feet consumed by the gas burner, by the illuminating power, as read off from the scale of the photometer; the product is the correct value of the gas, reduced to the standard of 120 grains per hour, and 5 cubic feet per hour.

THERMOMETERS.

The thermometer or "heat measurer" is an instrument for measuring the degree of heat exhibited by a substance as compared with an arbitrary standard; it only shows the relative and not the actual degree of heat contained in a substance. 80° is not equivalent to twice 40° and we cannot assume that a given weight of any substance, say 1 lb. of iron contains twice as much heat when at a temperature of 80° , as when it is at a temperature of 40° , for if we assume this, we also assume that, at the point of the scale which for convenience is marked "zero," there is a total absence of heat, which is not the case, for it is possible to obtain a much lower temperature.

The lowest point possible to obtain by artificial means is about 220° F.

Various scales are used with the thermometer; that of Fahrenheit being generally used in this country.

To properly gauge a thermometer tube by this scale, the instrument is dipped into melting ice and into boiling water.

The height of the mercury in the tube in each experiment is carefully noted, and the distance between the points is divided into 180 divisions.

To find the zero point, 32 divisions are added below the freezing point.

The Centigrade and Reaumur scale are used mostly in Europe. In the Centigrade thermometer the scale is divided into 100 equal parts, extending from the freezing to the boiling point. The Reaumur thermometer has the distance from the freezing to the boiling point divided into 80 divisions or degrees. The boiling point of water is according to Fahrenheit, 212° , according to Centigrade 100° , and according to Reaumur 80 . The zero of Fahrenheit was obtained by a mixture of ice or snow with salt.

Temperatures above 600° F. are measured by instruments known as pyrometers. This is an arrangement by which the expansion of a bar of metal is gauged, and rendered tangible on a dial.

To convert degrees of Fahrenheit into those of Centigrade and Reaumur, and conversely—

To convert Fahr. into Cent.—

RULE 1st.—Subtract 32, and divide the remainder by 1.8 thus :—

$$\text{Fahr. } \frac{167-32}{1.8} = 75 \text{ Cent.}$$

RULE 2d.—Subtract 32, multiply the remainder by 5 and divide the product by 9, thus :—

$$\text{Fahr. } \frac{167-32 \times 5}{9} = 75 \text{ Cent.}$$

To convert Cent. into Fahr.—

RULE 1st.—Multiply by 1.8 and add 32 thus :—

$$\text{Cent. } 75 \times 1.8 + 32 = 167 \text{ Fahr.}$$

RULE 2d.—Multiply by 9 divide by 5 and add 32 thus :—

$$\text{Cent. } \frac{75 \times 9 + 32}{5} = 167 \text{ Fahr.}$$

To convert Fahr. into Reau.—

RULE 1st.—Subtract 32, and divide by 2.25 thus :—

$$\text{Fahr. } \frac{113-32}{2.25} = 36 \text{ Reau.}$$

RULE 2d.—Subtract 32, multiply by 4 and divide by 9 thus :—

$$\text{Fahr. } \frac{113-32 \times 4}{9} = 36 \text{ Reau.}$$

To convert Reau. into Fahr.—

RULE 1st.—Multiply by 2.25, and add 32 thus :

$$\text{Reau. } 36 \times 2.25 + 32 = 113 \text{ Fahr.}$$

RULE 2d.—Multiply by 9, divide by 4 and add 32 thus :—

$$\text{Reau. } \frac{36 \times 9}{4} + 32 = 113 \text{ Fahr.}$$

PROPORTIONAL FORMULAS FOR THE THERMOMETRIC SCALE.

$$\text{Cent.} = \frac{5}{9} \text{ Reau.} = \frac{5}{9} \text{ Fahr. (Fahr.} = -32)$$

$$\text{Reau.} = \frac{4}{9} \text{ Cent.} = \frac{4}{9} \text{ Fahr. (Fahr.} = -32)$$

$$\text{Fahr.} = \frac{9}{5} \text{ Cent.} + 32 = \frac{9}{5} \text{ Reau.} + 32$$

TABLE.

Comparing Fahrenheit's, Reaumur's, and the Celsius or Centigrade Thermometers.

Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.	Fahr.	Reau.	Cent.
212	80.0	100.0	153	53.7	67.2	95	28.0	35.0	37	2.2	2.7
211	79.5	99.4	152	53.3	66.6	94	27.5	34.4	36	1.7	2.2
210	79.1	98.8	151	52.8	66.1	93	27.1	33.8	35	1.3	1.6
209	78.6	98.3	150	52.4	65.5	92	26.6	33.3	34	0.8	1.1
208	78.2	97.7	149	52.0	65.0	91	26.2	32.7	33	0.4	0.5
207	77.7	97.2	148	51.5	64.4	90	25.7	32.2	32	0.0	0.0
206	77.3	96.6	147	51.1	63.8	89	25.3	31.6	31	-0.4	-0.5
205	76.8	96.1	146	50.6	63.3	88	24.8	31.1	30	-0.8	-1.1
204	76.4	95.5	145	50.2	62.7	87	24.4	30.5	29	-1.3	-1.6
203	76.0	95.0	144	49.7	62.2	86	24.0	30.0	28	-1.7	-2.2
202	75.5	94.4	143	49.3	61.6	85	23.5	29.4	27	-2.2	-2.7
201	75.1	93.8	142	48.8	61.1	84	23.1	28.8	26	-2.6	-3.3
200	74.6	93.3	141	48.4	60.5	83	22.6	28.3	25	-3.1	-3.8
199	74.2	92.7	140	48.0	60.0	82	22.2	27.7	24	-3.5	-4.4
198	73.7	92.2	139	47.5	59.4	81	21.7	27.2	23	-4.0	-5.0
197	73.3	91.6	138	47.1	58.8	80	21.3	26.6	22	-4.4	-5.5
196	72.8	91.1	137	46.6	58.3	79	20.8	26.1	21	-4.8	-6.1
195	72.4	90.5	136	46.2	57.7	78	20.4	25.5	20	-5.3	-6.6
194	72.0	90.0	135	45.7	57.2	77	20.0	25.0	19	-5.7	-7.2
193	71.5	89.4	134	45.3	56.6	76	19.5	24.4	18	-6.2	-7.7
192	71.1	88.8	133	44.8	56.1	75	19.1	23.8	17	-6.6	-8.3
191	70.6	88.3	132	44.4	55.5	74	18.6	23.3	16	-7.1	-8.8
190	70.2	87.7	131	44.0	55.0	73	18.2	22.7	15	-7.5	-9.5
189	69.7	87.2	130	43.5	54.4	72	17.7	22.2	14	-8.0	-10.0
188	69.3	86.6	129	43.1	53.8	71	17.3	21.6	13	-8.4	-10.5
187	68.8	86.1	128	42.6	53.3	70	16.8	21.1	12	-8.8	-11.1
186	68.4	85.5	127	42.2	52.7	69	16.4	20.5	11	-9.3	-11.6
185	68.0	85.0	126	41.7	52.2	68	16.0	20.0	10	-9.7	-12.2
184	67.5	84.4	125	41.3	51.6	67	15.5	19.4	9	-10.2	-12.7
183	67.1	83.8	124	40.8	51.1	66	15.1	18.8	8	-10.6	-13.3
182	66.6	83.3	123	40.4	50.5	65	14.6	18.3	7	-11.1	-13.8
181	66.2	82.7	122	40.0	50.0	64	14.2	17.7	6	-11.5	-14.4
180	65.7	82.2	121	39.5	49.4	63	13.7	17.2	5	-12.0	-15.0
179	65.3	81.6	120	39.1	48.8	62	13.3	16.6	4	-12.4	-15.5
178	64.8	81.1	119	38.6	48.3	61	12.8	16.1	3	-12.8	-16.1
177	64.4	80.5	118	38.2	47.7	60	12.4	15.5	2	-13.3	-16.6
176	64.0	80.0	117	37.7	47.2	59	12.0	15.0	1	-13.7	-17.2
175	63.5	79.4	116	37.3	46.6	58	11.5	14.4	0	-14.2	-

TABLE.

TO FACILITATE THE CORRECTION OF THE VOLUME OF GAS AT
DIFFERENT ATMOSPHERIC PRESSURES.

Bar.	Ther 32°	34°	36°	38°	40°	42°	44°	46°	48°
28.0	998	993	988	984	979	974	970	965	960
28.1	1002	997	993	988	983	978	973	969	964
28.2	1006	1001	996	991	986	981	977	972	967
28.3	1009	1004	1000	995	990	985	980	976	971
28.4	1012	1007	1002	998	993	988	984	979	974
28.5	1016	1011	1006	1001	997	992	987	983	978
28.6	1020	1115	1010	1005	1001	995	991	986	981
28.7	1023	1018	1013	1009	1004	999	994	990	985
28.8	1027	1022	1017	1012	1007	1003	998	993	988
28.9	1031	1026	1021	1016	1011	1006	1001	997	992
29.0	1034	1029	1024	1019	1014	1010	1005	1000	995
29.1	1038	1033	1028	1023	1018	1013	1008	1004	999
29.2	1041	1036	1031	1026	1021	1017	1012	1007	1002
29.3	1045	1040	1035	1030	1025	1020	1015	1011	1006
29.4	1048	1043	1038	1033	1028	1024	1019	1014	1009
29.5	1052	1046	1041	1036	1032	1027	1022	1018	1013
29.6	1055	1050	1045	1040	1036	1031	1026	1021	1016
29.7	1059	1054	1049	1044	1039	1034	1029	1025	1019
29.8	1063	1058	1053	1048	1043	1038	1033	1028	1023
29.9	1066	1061	1056	1051	1046	1041	1036	1031	1026
30.0	1070	1065	1060	1055	1050	1045	1040	1035	1030

TABLE—CONTINUED.

Bar.	Ther. 32°	34°	36°	38°	40°	42°	44°	46°	48°
31.1	1073	1068	1063	1058	1053	1048	1043	1038	1033
30.2	1076	1071	1066	1062	1057	1052	1047	1042	1037
30.3	1080	1075	1070	1065	1060	1055	1050	1045	1040
30.4	1084	1079	1074	1069	1064	1059	1054	1049	1044
30.5	1087	1082	1077	1072	1067	1062	1057	1052	1047
30.6	1090	1085	1080	1075	1071	1066	1061	1056	1051
30.7	1094	1089	1084	1079	1074	1069	1064	1059	1054
30.8	1098	1093	1088	1083	1078	1073	1068	1063	1058
30.9	1101	1096	1091	1086	1081	1076	1071	1066	1061
31.0	1105	1100	1095	1090	1085	1080	1075	1070	1065

Bar.	Ther. 50°	52°	54°	56°	58°	60°	62°	64°	66°
28.0	956	951	946	942	937	932	927	922	977
28.1	959	955	951	945	941	936	930	926	921
28.2	963	958	953	949	944	939	934	929	924
28.3	966	961	957	952	947	942	937	932	928
28.4	970	965	960	955	951	946	941	936	931
28.5	973	968	964	959	954	949	944	939	934
28.6	977	972	967	962	958	953	947	943	938
28.7	980	975	970	966	961	956	951	946	941
28.8	984	979	974	969	964	959	954	949	944
28.9	987	982	977	973	968	963	958	953	948
29.0	990	986	981	976	971	966	961	956	951

TABLE—CONTINUED.

Bar.	Ther. 50°	52°	54°	56°	58°	60°	62°	64°	66°
29.1	994	989	984	979	975	969	964	959	954
29.2	997	992	988	982	978	973	968	963	958
29.3	1001	996	991	986	981	976	971	966	961
29.4	1004	999	995	990	985	980	975	969	964
29.5	1008	1003	998	993	988	983	978	973	968
29.6	1011	1006	1001	996	992	986	981	976	971
29.7	1015	1010	1005	1000	995	990	985	980	974
29.8	1018	1013	1008	1003	998	993	988	983	978
29.9	1022	1017	1012	1007	1002	997	991	986	981
30.0	1025	1020	1015	1010	1005	1000	995	990	985
30.1	1029	1024	1019	1014	1009	1003	998	993	988
30.2	1032	1027	1022	1017	1012	1007	1002	996	991
30.3	1036	1030	1025	1020	1015	1010	1005	1000	995
30.4	1039	1034	1029	1024	1019	1014	1008	1003	998
30.5	1042	1037	1032	1027	1022	1017	1012	1006	1001
30.6	1046	1041	1036	1031	1026	1020	1015	1010	1005
30.7	1049	1044	1039	1034	1029	1024	1018	1013	1008
30.8	1053	1048	1043	1037	1032	1027	1022	1017	1011
30.9	1056	1051	1046	1041	1036	1031	1025	1020	1015
31.0	1060	1055	1049	1044	1039	1034	1029	1023	1018

TABLE—CONTINUED.

Bar.	Ther. 68°	70°	72°	74°	76°	78°	80°	82°	80°
28.0	912	907	902	897	892	887	881	875	870
28.1	916	911	905	900	895	890	884	879	873
28.2	919	914	909	904	898	893	887	882	876
28.3	922	917	912	907	902	896	891	885	880
28.4	926	921	915	910	905	900	894	888	883
28.5	929	924	919	914	908	903	897	892	886
28.6	932	927	922	917	912	906	901	895	889
28.7	936	931	925	920	915	909	904	898	893
28.8	939	934	929	924	918	913	907	901	896
28.9	942	937	932	927	921	916	910	905	899
29.0	946	941	935	930	925	919	914	908	903
29.1	949	944	939	933	928	923	917	911	906
29.2	952	947	942	937	931	926	920	914	909
29.3	956	950	945	940	935	929	923	918	912
29.4	959	954	949	943	938	932	927	921	915
29.5	962	957	952	947	941	936	930	924	919
29.6	966	960	955	950	944	939	933	927	922
29.7	969	964	959	953	948	942	937	931	925
29.8	972	967	962	957	951	946	940	934	928
29.9	976	970	965	960	954	949	943	937	932
30.0	979	974	968	963	958	952	946	941	935
30.1	983	977	972	966	961	955	950	944	938

TABLE—CONTINUED.

Bar.	Ther. 68°	70°	72°	74°	76°	78°	80°	82°	84°
30.2	886	930	575	970	964	959	953	947	941
30.3	989	984	978	973	968	962	956	950	945
30.4	993	987	982	976	971	965	959	954	948
30.5	996	990	985	980	974	969	963	957	951
30.6	999	994	988	983	977	972	966	960	954
30.7	1003	997	992	986	981	975	969	963	957
30.8	1006	1000	995	990	984	978	972	967	961
30.9	1009	1004	998	993	987	982	976	970	964
31.0	1013	1007	1002	996	991	985	979	973	967

RULE FOR THE USE OF TABLE.

EXAMPLE—What will 1000 cubic feet of gas at 80° Fah. and 30.6 inches pressure, occupy at 60° Fah. and 30 inches pressure?

$$(60-32) + 480 \quad 30.6$$

$$\frac{\quad}{(80-32) + 480} \times \frac{\quad}{30} \times 1000 = 981 \text{ cubic feet. Answer.}$$

The weight of any quantity of air may be known by multiplying the quantity in feet by the tabular number, corresponding to the temperature and barometric pressure at the time, and by the decimals .07529 or .0753. Strike off the proper decimals, the answer will be the weight in pounds avoirdupois.

To find the weight of any quantity of Gas in pounds, the specific gravity being known.

RULE—Multiply the quantity in feet by the specific gravity and the product by .0766, and the answer will be the weight of gas in lbs.

EXAMPLE—What is the weight of 9400 cubic feet of gas its specific gravity being .480?

$$9400 \times .480 \times .0766 = 345.62 \text{ lbs. of gas.}$$

To find the weight of coal gas in a holder.

RULE—Multiply the number of *thousands* of cubic feet contained in the holder by 37, and the product will be the weight of the gas in lbs.

EXAMPLE—A holder contains 54,000 cubic feet of gas what is the weight of the gas?

$$54 \times 37 = 1998 \text{ lbs. approximate weight of gas.}$$

BUOYANCY OF GAS.

For ordinary coal gas of 0.450 specific gravity the buoyancy or ascending power = $42\frac{1}{2}$ lbs per thousand cubic feet, in a holder 80 ft. dia. and 21 ft. deep, = $5026.5 \times 21 = 105.557$ cubic feet. capacity. $105.5 \times 42.5 = 4483.75$ lbs buoyancy, and every $\frac{1}{10}$ th pressure = 2618 lbs. and $\frac{4483.75}{2618} = 1\frac{71}{100}$ tenths lighter with gas.

TEMPERATURE OF GAS.

The standard temperature for measurement, and comparisons for gases, is 60° Fahr. with the barometer at 30° pressure. All gases and air, expand for each degree above 32° Fahr. $\frac{1}{480}$ of their bulk or about 1 per cent. for 5°.

The quantity of heat which will raise a cubic foot of water one degree, will raise 2850 cubic feet of gas or atmospheric air to the same extent.

It is therefore of the greatest importance, in making comparisons of results, that the temperature of the gas and the barometric pressure should be noted. In taking the specific gravity, and in testing the illuminating power of gases, the temperature of the gas, at the time and place of experiment should be recorded.

TABLE.

EXPANSION OF AIR AND PERMANENT GASES BY HEAT.

Temp. Fahr.	Expan- sion.	Temp. Fahr.	Expan- sion.	Temp. Fahr.	Expan- sion.	Temp. Fahr.	Expan- sion.
32	1000.0	52	1041.6	72	1083.3	92	1125.0
33	1002.1	53	1043.7	73	1085.4	93	1127.1
34	1004.2	54	1045.8	74	1087.5	94	1129.1
35	1006.2	55	1047.9	75	1089.6	95	1131.2
36	1008.3	56	1050.0	76	1091.6	96	1133.3
37	1010.4	57	1052.1	87	1093.7	97	1135.4
38	1012.5	58	1054.1	78	1095.8	98	1137.5
39	1014.6	59	1056.2	79	1097.9	99	1139.5
40	1016.6	60	1058.3	80	1100.0	100	1141.6
41	1018.7	61	1060.4	81	1102.1	110	1162.5
42	1020.8	62	1062.5	82	1104.1	120	1183.3
43	1022.9	63	1064.5	83	1106.2	130	1204.1
44	1025.0	64	1066.6	84	1108.3	140	1225.0
45	1027.1	65	1068.7	85	1110.4	150	1245.8
46	1029.1	66	1070.8	86	1112.5	160	1266.6
47	1031.2	67	1072.9	87	1114.6	170	1287.5
48	1033.3	68	1075.0	88	1116.6	180	1308.3
49	1035.4	69	1077.1	89	1118.7	190	1329.1
50	1037.5	70	1079.1	90	1120.8	200	1350.0
51	1039.6	71	1081.2	91	1122.9	212	1375.0

TABLE.

GIVING THE PROPORTIONS OF AQUEOUS VAPOR, EXISTING IN ANY GAS STANDING IN CONTACT WITH WATER, AT THE CORRESPONDING TEMPERATURE AND AT THE MEAN BAROMETRIC PRESSURE OF 30 INCHES. (DALTON & URE.)

Tempe- rature. Deg.	Volume of Aqueous vapor.	Tempe- rature. Deg.	Volume of Aqueous vapor.	Tempe- rature Deg.	Vo.lume of Aqueous vapor.
40	.00933	54	.01533	68	.02406
41	.00973	55	.01586	69	.02483
42	.01013	56	.01640	70	.02566
43	.01053	57	.01693	71	.02653
44	.01093	58	.01753	72	.02740
45	.01133	59	.01810	73	.02830
46	.01173	60	.01866	74	.02923
47	.01213	61	.01923	75	.03020
48	.01253	62	.01980	76	.03120
49	.01293	63	.02050	77	.03220
50	.01333	64	.02120	78	.03323
51	.01380	65	.02190	79	.03423
52	.01426	66	.02260	80	.03533
53	.01480	67	.02330		

METER INSPECTION.

From the reports of meter inspection in Massachusetts, some ideas can be gleaned in regard to the reliability of that much abused instrument.

For the year 1885, the number of old meters inspected was 178. Of this number, 51 registered against the consumer, the average error being four and twenty-two hundredths per cent. One hundred were within the limits allowed by law, namely two per cent. either way; 25 registered against the companies, the average error being five and two hundredths per cent.

The average error of all the above meters tested was fifty-eight hundredths of one per cent. against the consumer. One meter leaked, and another would not register. The above were all dry meters. All the above tests were of meters against which complaint was made by the consumer—therefore it is fair to assume that they were faster than those against which no complaint was made. The consumer having the meter noted above as not registering must have been of angelic nature, to complain of a meter for *not* registering, but perhaps he thought it better to have a meter that registered, than to let the Company's officers *guess* at the amount.

Taking the years from 1872 to 1881 inclusive, the percentages of fast, correct and slow meters complained of is as follows.

Fast 935, correct 1148, slow 361. Whole number 2444.

During the years since the above inspections were made, an improvement has been made, and the complaints have been less.

The improvement is no doubt due, to the fact that the gas is much better purified from ammonia than in former years. Ammonia attacks the leather diaphragms of meters causing them to contract at first and finally if there is much ammonia in the gas, the diaphragms become rotten and crack.

GAS INSPECTION, CANDLE POWER, SULPHUR AND AMMONIA.

The Gas Inspectors for the State of Massachusetts made during the year 1884, over five hundred inspections of gas furnished by sixty-six Companies. Each inspection comprised a determination of the candle power, and also the amount of sulphur and ammonia in the gas. The tests were made generally at a distance from the works.

The average candle power of 28 companies, was 17.71, ranging from 19.37 to 16.95.

The average candle power of 32 companies was 17.61, ranging from 19.65 to 16.32, the lowest allowed by law is 15 candle power.

The number of grains of sulphur per 100 cubic feet, average for 28 companies, was 10.32 ranging from 13.01 to 6.74.

The same for 32 companies was, 8.11 ranging from 13.17 to 4.63.

The number of grains of ammonia per 100 cubic feet, average for 28 companies was, 4.15 ranging from 13.35 to 1.00.

The same for 32 companies was, 5.19 ranging from 21.07 to 1.00.

The amount of sulphur and ammonia, while large in one or two exceptional cases, are less than during the previous year. Ten grains of ammonia per 100 cubic ft. is the legal allowance.

SIZES OF TUBING, METERS, ETC.

Size of Tubing.	Greatest length allowed.	No. of Burners.
$\frac{1}{4}$ inch	6 feet	1 burner
$\frac{3}{8}$ "	20 "	3 "
$\frac{1}{2}$ "	30 "	6 "
$\frac{5}{8}$ "	40 "	12 "
$\frac{3}{4}$ "	50 "	20 "
1 "	70 "	35 "
$1\frac{1}{4}$ "	100 "	60 "
$1\frac{1}{2}$ "	150 "	100 "
2 "	200 "	200 "

Sizes of Meters	Greatest No. of Burners.
3 lights	5 burners
5 "	10 "
10 "	20 "
20 "	40 "
30 "	60 "
45 "	100 "
100 "	250 "

TESTING METERS.

To arrive at an accurate result in testing Gas Meters, too much care cannot be taken. Connecting a Meter to the Prover, and passing a small quantity of gas or air through it (without a strict regard to the following rules), is simply an approximation—not a test.

To test a Meter accurately, the Prover must be mathematically correct, duly counterpoised and adjusted, so as to give a uniform pressure from top to bottom. Next the water in the Prover, as also the gas or air in Holder must be uniform in temperature with the air of the room in which the experiment is to be conducted, and *all* of them kept uniformly so during the experiment. These points ascertained and found correct, the Meter may be connected to Holder, and a small quantity of air or gas admitted, to bring the pointer on index to any desired point on the scale; next adjust the pointer on Holder to O, or any other point on the scale, being very particular to take both these observations carefully, then turn on gas or air to Meter, and make one or more complete revolutions of pointer on Dial, *always stopping exactly on the point started from*. If the quantity registered by the Meter exactly corresponds with that taken from the Holder, the Meter is correct; but if more or less, the percentage of error is easily calculated.

In testing Wet Meters, water of same temperature of the other elements (before mentioned) should be used—set them on a perfectly level plate, and allow the water to run as low as it will from the side (or water line) screw, which is the true level, and observe rules as above.

Meters are usually tested at a pressure of from 1 to $1\frac{1}{2}$ inch at inlet pipe (which should always be fully supplied with air or gas), the outlet of Meter being reduced to a given quantity per hour as in table below.

Temperature is not particular, but it is absolutely necessary that all the elements before named should be *strictly* uniform during the whole time of testing.

OUTLET OPENINGS, WHEN TESTING.

2 light Meter,	12 feet per hour,
3 " "	18 " "
5 " "	30 " "
10 " "	60 " "
20 " "	120 " "
30 " "	180 " "
45 " "	270 " "
60 " "	360 " "
80 " "	480 " "
100 " "	600 " "
150 " "	900 " "
200 " "	1200 " "

THE ADVANTAGES OF GAS FOR COOKING PURPOSES.

In addition to the advantages which gas presents as an economical means of illumination. It is also applicable, as a cheap and convenient substitute for ordinary fuel. Under certain conditions, and with properly arranged apparatus it competes favorably with coal for the purpose of cooking, and when a fire is required, only occasionally, and for a short time, it has an undoubted advantage over coal, as to cost and convenience. By the use of atmospheric burners the gas is mixed with atmospheric air, at the moment of ignition producing a blue flame of great heat, which does not deposit carbon or soot as gas would if burned through the ordinary burner.

The following statement, which is the result of many experiments, shows the relative cost of boiling a gallon of water in a copper kettle, by means of a recently lighted coal fire, and by a gas stove, and the time required in each case :

	Coal used	Wood used	Time employed	Total cost
With Fire.	4½ lbs.	4 cts	1 hour	1.54 cts.
With Gas.	4 Cubic Feet at \$1.12		20 minutes	44 cts.
	per 1000.			

It appears therefore that for occasional purposes, there is a saving of nearly 3½ to 1 in money, and an economy of ⅔ ds in time by the use of gas, in addition to the saving of trouble in lighting the fire, and the avoidance of smoke and dust.

The following tables give the results of experiments made by Mr. M. Ohren, and the comparative loss of cooking by coal and by gas; the former being taken at \$5 50 per ton and the latter at \$1.10 per thousand cubic feet.

GAS.

Joint.	Weight		Time.		When cooked with Drippings		Loss.		Gas used Cubic Feet.	Cost of Gas at 1.10 per M. cts
	lbs.	oz.	hrs	min	lbs	oz.	lbs.	oz.		
Leg of mutton.	8	1½	2	20	7	10		7½	41	4.51
Rib of Beef....	10	14	2	37	10	0½		14	46	5.06
Leg of Mutton	9	7	2	30	8	13½		9½	42	4.62
Rib of Beef....	11	0	2	45	10	1½		14½	48	5.28
	39	6½	10	12	36	8½	2	13½	177	19.47

COAL.

Joint.	Weight.		Time.		When cooked with Drippings.		Loss.		Cost of coal and wood. cts.
	lbs.	oz.	hrs.	min.	lbs.	oz.	lbs.	oz.	
Leg of mutton.	8	1½	2	50	7	8½		8½	7.72
Rib of beef....	10	14	2	45	9	15½		14½	7.84
Leg of mutton.	9	12	2	30	9	0		12	7.60
Rib of Beef....	13	2	2	50	12	3		15	8.06
	41	13½	10	55	38	11½	3	2	31.22

From the above it will be seen that the advantage is decidedly on the side of gas, as far as the actual cost is concerned, with the additional one, that immediately the cooking is over, the gas is turned off, and there is no future consumption and waste, as in the case of cooking with a coal fire.

In cooking meat by gas it is roasted, not baked as in the common cooking oven; the difference being in baking that the meat is excluded from the air, while in the furnace it is exposed to a continual current of air, which gives to roast meat that peculiar flavor, which baked meat has not.

In a cooking contest, carried on between the "Peerless Range" burning coal, and a "Sun Dial" gas stove (Goodwin Gas Stove and Meter Co., Phila. Pa.) the following record was made.

The same kinds and amounts of food were cooked on each, and consisted of Fish, Beef, Chicken, Steak, Chops, Potatoes, and other vegetables; Bread, Pudding and Pie, together with sauces for Beef, Fish and Cauliflower.

For the coal range, the total time from lighting the fire until everything was ready to serve, was 2 hours and 40 minutes. Of this time 30 minutes was required to heat the oven, leaving 2 hours and 10 minutes actual cooking time. Weight of coal, including lighting of fire, 44 lbs. At the end of the time the fire was ready for more coal. Cost of coal, 44 lbs., at \$5.50 per ton — 10.95 cts. Kindling 1 cent. Total 11.95.

For the "Sun Dial" gas stove. Total time from lighting the gas until everything was ready to serve, 1 hour and 50 minutes. Consumption of gas by test meter, 38 feet. At \$1.25 per thousand feet, cost 8.17 cents.

Cost of Coal.....	11.95
" " Gas.....	8.17

Saving over Coal..... 3.78 cts. — 46 per cent.

The loss of weight by cooking was also much greater by the coal than by the gas oven.



The makers of this gas cooking stove, claim for it—the following advantages over coal stoves. 1st. More healthful, through the absence of waste heat, soot, smoke, dust, and smell. 2d. More certain by the rapidity of manipulation, in consequence of the simplicity of construction. 3d. Less troublesome, requiring very little attention during the process of cooking. 4th. Less expensive. 5th. Less wasteful, through loss of weight; the juices and fat instead of being separated as in the ordinary process, remain thoroughly incorporated with the meat, a point of great importance in a material as well as an economical sense.

Above all other advantages, the convenience of gas stoves, stands first. Like the gas engine, a simple turning on and off of the gas, takes the place of slow kindling, and the dirty and dusty cleaning out and carting away of ashes. When the cooking is done, the gas can be partly turned down, and the viands kept warm, till wanted on the table. The time is no doubt near at hand when cooking will be done almost entirely by gas. Hotel ranges are now made capable of cooking a dinner for from 100 to 1000 persons.

Hot water generators are also used, for heating water for wash basins and bath tubs, thus finally usurping every function of the coal range.



GOODWIN GAS HEATING STOVE.

The enormous number of flats and apartment houses, springing up with mushroom activity in all our large cities, has stimulated the manufacturers of gas stoves, for heating and cooking—which stoves, combining both economy and convenience, and occupying a small space are especially adapted to this class of buildings.

Gas stoves are also used extensively by confectioners, and also for laundry purposes.

A writer on the subject of the use of gas for heating, and cooking says: “The experience of the last 30 years has proved its efficiency for almost every domestic purpose, and its convenience and cleanliness as compared with coal, will be recognized after a moments reflection.

Two of the three prime necessities of civilized house keeping—water and light—are now provided in our houses without carriage, and the third will ere long carry itself.

In most instances coal is dumped at our gates, or into our cellars, and has to be carried, at an expenditure of labor, to its

place. When a fire is wanted in the upper part of the house, some one has to descend to the cellar, shovel up the coal, and bear it by hand up the stairs to its destination. At the mine coal lifts and carries coal; in our houses the work is done by human muscle. In the process of feeding the fire the coal is again handled, and in carrying out the ashes, more disagreeable work has to be done, and dust and dirt scattered around. The fire must be also watched, and regulated, each step costing time and labor. Further the burning of coal in small quantities is wasteful in the extreme. The combustion is imperfect, only a fraction of the possible heat is obtained, and much of that is wasted in the chimneys. A large percentage of the coal is consumed when no heat is required, in order that the fire may be ready when it is wanted. In short there are a thousand ways in which the cost of coal is augmented, by the crude and unscientific use of it for household purposes—ways not suspected by those who have never used a fuel which has none of the drawbacks of coal; which burns clearly, perfectly, and requires no carrying—namely gas.

The secret of the economy of cooking by gas, when properly applied can be told in a few words. *There is no fuel wasted.* Its full heating power is developed just where and when it is wanted, and in just the quantity wanted.

The facts and reasonings adduced above, certainly show that gas, as applied to cooking, is in comparison with other fuel.

1. More healthful.
2. More certain.
3. Less troublesome.
4. Less expensive.
5. Less wasteful,

and certainly much cleaner.

One point has sometimes been raised against the use of gas for cooking purposes, and that can be easily shown to be of no account whatever—this point is that the products of combustion, poisonous gases, taint the food. Against this it can be said that gas and coal are composed of precisely the same elements, and these elements on combustion yield the same products, and whereas the sulphur is taken from the gas in purifying, the coal is not purified and yields its sulphurous fumes on combustion and in much greater quantity than would be possible even in unpurified gas.

As it is obvious, that the duty of every gas manager is to increase the quantity of gas sold, whether for illuminating or other purposes, thereby securing the company's property from depreciation resulting from the introduction of rival lights, it remains but to suggest ways of increasing the demand. This can be done by lectures and exhibitions of gas cooking, by distributing pamphlets on the subject, and by the letting of gas stoves on trial, or by selling them on the installment plan.

A GAS COOKING DEMONSTRATION.

CONDENSED FROM LONDON JOURNAL OF GAS LIGHTING.

At the invitation of Mr. W. Sugg a party of ladies and gentlemen assembled to listen to a few remarks on cooking by gas, and afterward to test the matter by partaking of the viands thus prepared. Mr. Sugg said: "That the result of many years practical work in the preparation of food with the aid of ordinary coal gas had led him to follow the plan adopted by the early workers in the field from whom he had received his first lesson in the work, he has carried on in this direction. These gentlemen considered the radiant heat produced by an intense luminous flame to be most useful for cooking operations, and he confessed to be their faithful disciple. He has remained a persistent believer in the white, as being superior to the blue or Bunsen flame for this special purpose; and he has gone on improving his apparatus with this belief as a fundamental principle.

One very grave objection formerly raised to the use of gas stoves was that they emitted a disagreeable odor. This has now been remedied by the use of steatite instead of iron for the burners. Mr. S. explained that the advantage of employing luminous flames was, that the product of combustion from these flames, being carbonic acid largely diluted with air could not in any way be prejudicial to the meat while the heat radiated from them struck and penetrated it in the process of cooking.

Speaking of economy he stated that one of his kitchen ranges is at work daily, cooking a dinner sufficient for 25 persons at a cost of about 4½ cts. for gas; (this is in London) the loss of weight of meat being from 8 to 12 per cent., as against 25 per cent. loss with the ordinary coal fire. Adding to these tangible economies,

the saving of labor, and the superior flavor of the meat insured by the adoption of cooking by gas, there is such a preponderance of advantage on the side of this system, that as soon as the value of gas cooking becomes fully known, the use of coal fires for the preparation of food will be abandoned in every well regulated household.

THE AMOUNT OF LIGHT OBTAINED FROM ONE TON OF OIL. *

Kind of Tests	Kind of Oil.	Yield in Cubic Feet.	Candle Power.	Equiv. in lbs. Sperm.	Equiv. yield per Ton of 65 Candle Gas.	Name of Experimenter.
Gas....	Whale....	22400	52.50	4032	18080	Mathews.
Gas....	"	17472	28.00	1596	7150	Dr. Fyfe.
Lamps.	Petroleum.	44473	15.00	2270	10180	Silbeo.
"	"	190930	15.00	9923	44480	"
"	Sperm...			3360	15067	Dr. Mcadam.
"	Rape			3103	13914	"
"	Whale....			3091	13861	"
"	Paraffins..			7420	33723	"
"	Crude Par.					"
"	affine			5565	24955	"
"	Petroleum.	111370	15.00	5727	25681	Dr. Chandler.
Gas....	Paraffine..	23240	34.76	2769	12417	Dr. Mcadam.
"	"	24400	42.00	3165	14192	Sommerville.
"	Petroleum	34865	100.00	11996	53793	Edgerton.
"	"	25900	70.00	6216	27874	Patton.
"	"	33294	52.60	6004	26923	Prof. Wagner.
"	"	26903	45.73	4212	18888	Lamson.
"	"	29411	53.48	5390	24063	"

*From a paper read before the Society of Gas Lighting, Feb'y 3d, 1876, by Mr Eugene Vanderpool.

PROPOSED STANDARDS OF LIGHT.

The use of a candle as a standard of comparison of light has always been regarded as uncertain and unreliable. Of late years this subject has received unusual attention and several substitutes have been brought forward. The Carcel lamp—used as a standard light in France, has been proposed. This lamp is of absolute dimensions, and consumes 648 grains (42 grammes) of colza oil per hour, under certain specified conditions.

Professor Hartley says in his *Manual* that after obtaining several of these standard lamps, wicks and oil from Paris, and conducting with them a series of several hundreds of very careful experiments; the results forced him to the conclusion that the Carcel lamp, while demanding more trouble and attention than sperm candles, was, as a standard, but little if any, more to be relied upon for constancy of light.

M. Monnier, after making a number of careful tests with the standard Carcel lamp, found that it gave a light equal to $8\frac{2}{100}$ normal English sperm candles, or $7\frac{5}{10}$ normal German sperm candles.

KEATES' LAMP.

This was called the Moderator lamp and was suggested as a standard light for illuminating power by Mr. Keates in 1869. Sperm oil was used on account of its greater fluidity and its low specific gravity. The consumption of oil was 750 to 760 grains per hour, and the light yielded equal to about 10 sperm candles.

Improvements have since been made by Mr. Wm. Sugg, which have raised the hourly consumption of oil to about 980 grains, and the light yielded to about 16 candles.

The original inventor is still experimenting with it.

FIDDES' LIGHT.

The principal feature of this proposed standard of light was an Argand lamp, having an opaque chimney with a circular hole about one-quarter inch diameter through which the light passes; so far it has not been a success.

METHVEN'S LIGHT.

This lamp differs from the above only in having the light pass through a vertical slot $\frac{1}{4}$ inch wide and 1 inch long, cut in an opaque screen; the burner used was an Argand No. 1. The screen being placed very near to and at a fixed distance from the burner. A very close approximation to the illuminating power of the gas may be obtained by this system.

HARCOURT'S STANDARD FLAME.

The nearest approach to a successful standard of light has been made by Mr. Vernon Harcourt. The standard combustible used by him consists of a "mixture of air with that portion of

American petroleum, which after repeated rectifications distills at a temperature not exceeding 50°C (122°F). The liquid thus obtained consists almost entirely of pentane, the fifth member of the paraffine series of hydrocarbons.

Its vapor density was found to be 37, the theoretical density of gaseous pentane as compared with hydrogen being 36.

The liquid used in the experiments made has a specific gravity between .628 and .631.

The standard gas is made by mixing a measured quantity of air in a small gas-holder. For every cubic foot of air the required volume of pentane is three cubic inches. Complete diffusion and volatilisation will take place in about 5 hours. At 30-inches barometer and 60°F and no pressure on the gas the volume of the latter should be 4.05 cubic feet, if 9 cubic inches of pentane have been added to 3 cubic feet of air. The gas is burned with a burner, having a hole in the top one-quarter inch in diameter. With pentane gas burning at the rate of one-half cubic foot per hour, a steady flame is produced $2\frac{1}{4}$ inches long, and equal to the average light given by a standard sperm candle.

The gas does not seem to deteriorate in quality, but is only subject in that respect as all gases are, to increase and diminution in density under changes of pressure and temperature. During the current year there has been appointed a special committee by the Metropolitan Board of Works of London, to investigate and report on the proposed substitution of a new standard of light for the standard sperm candle. 2120 experiments were made with 20,000 recorded observations, the results obtained show more than ever the unreliability of the sperm candle as a standard of light.

This committee have experimented with the Keates lamp and have found that it failed in practice to realize what was formerly expected from it. The Methven slotted screen and other inventions were tried but with no very striking results.

A new standard lately brought forward by Herr von Hefner Ateneck, called the Amyl-acetate flame, has attracted much attention, and may be briefly described as a lamp burning amyl-acetate with a round solid wick. The lamp has a straight glass chimney to protect the lamp from draughts. The flame was found to be very steady, but the color of the light rendered it difficult for different operators to agree; this effect was clearly shown when compared with the pentane light.

The tendency at present is to insist as far as possible upon a white light from all artificial sources. The requirements for a standard of comparison of light are given as follows:

1.—It should have a definite combustible material.

2.—The condition in which that combustible material exists at the time of use should be under control and capable of inspection for verification.

3.—The rate of combustion and the manner in which it is effected, should be readily and accurately observed.

The pentane air-gas standard was found to meet every requirement made upon it and to fully answer all the claims made for it by the inventor.

The facts brought out by this inquiry have shown that the method of preparing the air gas is at once easy and safe; that the adjustment of the height of the flame is a matter of certainty; its steadiness all that can be desired when due care is taken and proper apparatus employed, and that the color of the light afforded is precisely the same as that of the standard comparison gas flame.

The following table gives a comparison of the results of many tests made with different proposed standards:

Standard	Total No. of Tests.	No. within 1 per cent. of the mean.	Percentage No. within 1 per cent. of the mean.
Candles.....	454	154	34
Keates lamp.....	244	98	39
Pentane.....	468	373	80
Methven.....	283	211	74
Ten candle test.....	49	43	88
Pentane Argand.....	243	212	87
Amyl-acetate....	225	206	90
Pentane lamp.....	154	150	97
Total.....	2,120		

Another table of comparative values from the same report is as follows:

Average.	Candles Pentane.		Pentane Lamp.	Methven Screen.
74	19.2	16.6	16.6	16.6
77	15.8	15.8	15.7	15.0
80	18.0	16.1	16.1	16.0
89	19.5	16.6	16.7	17.0

It would seem from the above tables that the sperm candle is by comparison the most uncertain of all standards; no doubt the present agitation on the subject will soon develop a new standard which can be universally adopted.

THE DETECTION OF AMMONIA AND OTHER IMPURITIES IN GAS.

Ammonia can be detected in gas :—

1.—By its action upon the color of turmeric paper, or reddened litmus paper.

2.—By its giving a white precipitate, when the fumes of hydrochloric acid are brought into contact with the gas.

3.—By passing gas through hot lime and then over test paper or through acid.

4.—The *quantity* present may be estimated by passing the gas through acid and determining the quantity which the acid has taken up by test alkali, or by chloride of platinum.

Ammonia changes the yellow color of turmeric to a red brown and of reddened litmus paper to a full blue. These changes of color are temporary only, for owing to the volatility of ammonia it flies off and leaves the reddened litmus red and the turmeric yellow, as they were before they were affected by the ammonia.

To apply these tests the paper is slightly damped so that the ammonia may be absorbed, and held in the stream of gas issuing from a burner. Generally the turmeric paper becomes brown, and the red litmus paper blue, in less than one-quarter of a minute. If on a longer exposure the colors are not changed, the gas does not contain any *free* ammonia.

Ammonia is also detected by dipping a glass rod or a feather into hydrochloric acid and holding it in a stream of gas, when, if the impurities are present, a white cloud of sal-ammoniac will be formed.

The presence of carbonic acid in the gas may be detected by causing the gas to bubble through lime water. If carbonic acid is present the water will become milky. The quantity of CO_2 is determined by receiving the gas in a graduated tube over mercury—and passing up a solid ball of potash or a few drops of a strong solution of potash. The carbonic acid is absorbed by the alkali, and the amount of condensation gives the percentage of the compounds present.

TO PREPARE LIME WATER.—To a quart of pure water add three or four ounces of quick-lime ; give it time to dissolve, after which decant the clear fluid, which is as transparent as pure water.

WATER GAS APPARATUS.

All water gas apparatus consists essentially of two cupolas, made of wrought iron and lined with fire brick. One is known as the "generator" and the other as the "superheater."

The former is charged with coal or coke to the depth of 3 to 5 feet, and the latter packed loosely with broken fire-brick with the exception of a space or "gas chamber," 3 or 4 feet square at the base. A flue or pipe passes from the top of the generator to the bottom of the superheater. The fuel in the generator is ignited and by means of a blast, it is brought to full incandescence ; while at the same time the packing in the superheater is raised to a white heat.

During this part of the operation the gases escape into an ordinary chimney by a suitable communication.

As soon as sufficient heat is obtained, the air-blast valve and the opening to the chimney are closed, steam is admitted below the fuel, and crude oil or naphtha run in on the top. The gases thus formed are conducted through the superheater into a condensing or purifying plant of the ordinary kind. After a time it is necessary to "get up the heat again," and so operations are carried on alternately. The steam is turned on first when commencing to make gas, and some judgment is necessary in regulating the oil supply. The best results obtained when making at the rate of 300,000 cubic ft. per day have been 1,000 cubic ft. of 20-candle gas from 50 lbs. of hard coal or coke and 4 gallons of naphtha ; and the apparatus above described is usually erected in duplicate so that the production of gas is continuous.

WATER GAS.—THE TESSIE DU MOTAY PROCESS.

Anthracite coal or coke is placed in an upright "gasogen" or cupola, ignited, and raised to incandescence by a strong air-blast ; the blast is then shut off and superheated steam is introduced.

The hydrogen of the steam is set free and the oxygen unites with the carbon in the coal, forming carbonic oxide and carbonic

acid—the proportion of each being about 50 per cent. of hydrogen, 40 per cent. of carbonic oxide, and 10 per cent. of carbonic acid—the proportion of the two latter varying with the heat.

This alternating the steam and air, requires about equal times of 10-minutes each.

The gas is generated and collected only during the time the steam is passing through the red-hot coal; while the air-blast is on, the gas outlet is closed, and the products of combustion are allowed to escape.

From the cupola the gas passes through the usual condensers, scrubbers and purifiers, similar to, but of greater capacity than those used for coal gas.

The hydrogen or “water gas” thus produced has no illuminating power, and is consequently stored in a separate holder, from which it is conducted into a carburetter or “illuminator.” This is a wrought iron chamber containing shallow pans of naphtha, heated by steam pipes, and so arranged that the gas, in its passage through, flows over the surface of the naphtha, and becomes saturated with its vapors. From thence the vaporized hydrogen passes through clay retorts, kept at a high temperature, where it becomes a fixed gas. It is then carried through a hydraulic main, to remove any free vapor that may have escaped decomposition in the retorts.

As the patents for this process have long ago expired, if they ever did have any life, the process is free to any one to use, any claims now held being for minor details of doubtful utility.

The merits claimed for this process, are its cheapness of production, the cleanliness of the works where it is produced, and the superior quality of the gas. Its opponents say that the first claim is *very* doubtful, and subject to the varying price of naphtha, and raise the great objection to its poisonous qualities owing to the great percentage of carbonic oxide.

A fair analysis of water gas gives—

Hydrogen.....	49.32	per cent.
Marsh gas.....	7.65	“ “
Carbonic oxide.....	37.97	“ “
Carbonic acid.....	0.14	“ “
Nitrogen.....	4.79	“ “
Oxygen.....	0.13	“ “

100.00 per cent.

TABLE.

SHOWING THE ANALYSIS OF WATER GASES MADE BY VARIOUS PROCESSES—1845 TO 1877.

PROCESS.	H.	CO.	CO ₂	CH ₄	N	AIR.	H ₂ O.	SUN-DRIES	DATE	NOTA	ANALYSTS.
Seguin, Johard, Pelletau	60.00	20.00	10.00	10.00	.....	.....	.....	.....	1845	g	William Graham.
White.....	52.70	38.30	8.40	.....	.....	.....	.....	.....	1851	.....	Dr. Frankland, F. C. S.
Gillard.....	76.30	14.70	2.00	.....	.....	.....	2.00	.....	1853	a	{ Mathieu, Baruel, Jacquelin
White.....	60.00	20.00	20.00	.....	.....	.....	.....	.....	1853	.....	T. G. Barlow, C. E.
Kirkham.....	.....	35.00	.....	.....	.....	.....	.....	.....	1855	.....	Dumas, Chevreul.
Kirkham.....	.....	40.00	.....	.....	.....	.....	.....	.....	1855	.....	Regnault.
Ordinary Retorts	53.30	40.20	6.50	.....	.....	.....	.....	.....	1861	h	Sainte-Claire, Deville.
Ordinary Retorts	52.50	42.50	5.00	.....	.....	.....	.....	.....	1861	i	H. Debray.
White.....	64.00	18.00	18.00	.....	.....	.....	.....	.....	1861	b	G. Howitz.
Gillard.....	94.08	3.54	0.50	0.88	.....	.....	1.02	0.48	1859	c	Verver.
Gwynne-Harris.	48.82	28.63	13.08	3.34	4.45	Trace	.....	1.68	1869	.....	Prof. Silliman and
Gwynne-Harris.	48.96	30.66	13.03	2.92	2.88	1.15	.....	0.40	1869	.....	Wertz
Tessie du Motay	28.00	33.00	1.00	16.00	7.00	.....	.....	15.00	1876	.....	Moses C. V. and A. M.
Tessie du Motay	30.60	35.00	2.00	13.00	10.30	.....	.....	9.00	1876	j	Smith & G. W. Dresser.
Lowe.....	30.64	27.40	4.27	22.54	1.09	.....	.....	13.89	1877	.....	Prof. Henry Morton.
Lowe.....	31.31	26.25	3.83	23.70	0.49	.....	.....	14.34	1877	.....	" "
Lowe.....	.....	26.54	.....	.....	.....	.....	.....	.....	1877	.....	" "
Lowe.....	47.60	41.26	6.23	4.60	.....	.....	.....	.....	1877	d	" "
Lowe.....	69.75	17.75	Trace	.....	5.00	.....	.....	7.50	1876	e	{ Dr. Schuessler and
Lowe.....	65.25	34.00	1.75	.....	.....	.....	.....	.....	1876	f	{ E. Vanderpool.
Strong.....	53.80	39.40	.....	4.30	.....	.....	.....	4.00	1877	.....	P. H. Vander Weyde.

NOTES EXPLANATORY OF TABLE.

(a) Gillard aimed at the production of CO_2 in preference to CO , as the former can be easily taken out by lime, whereas the removal of the latter is a very costly, and difficult operation. The charcoal which enters into the composition of the CO_2 is by this system entirely lost and the consumption of lime almost exceeds belief, being at the rate of more than two bushels for each 1000 cubic feet of gas stored in the holder.

(b) Iron retorts were used, and part of the O combined with the iron, thus increasing the percentage of H.

(c) The same note is applicable here, as in case (a).

(d) These figures are obtained by proportion from the analysis of the illuminating gas.

(e) This gas was a compound one, it being taken from the street mains of the Utica Gas Co., which company at the time was making a mixed coal oil, and water gas.

(f) This gas was taken from the outlet of the condenser of the Lowe apparatus, the generator or gasogen having been run some time without any oil, so as to furnish a fair sample of pure water gas.

(g) Modified process.

(h) Low heats.

(i) High heats.

(j) Illuminating gas.

From a paper on the Strong Water Gas Process for making heating gas by E. Vanderpool.

THE MARTIN WATER GAS PROCESS.

This process employs the usual apparatus, common to nearly all water gas processes, viz., the cupola or generator and super-heater, but differs from them in the manner of introducing and evaporating the oil. Usually the oil is dropped on the bed of incandescent fuel, and is liable to form lampblack in consequence of the excessive heat to which it is exposed at the first part of the "run" and at a later period is not wholly converted into a fixed gas owing to a lack of heat. The use of an enriching oil directly upon the fuel materially reduces the heat and shortens the run—thus necessitating more frequent use of the blast to raise the heat to a gas-producing point. To prevent the formation of lamp-black, conserve the heat of the incandescent coal in the generator by relieving it of the duty of converting the oil into gas; increase the length of gas-making duty in each "run," and to decrease the

costly and time-consuming blowing up periods, are the objects and claims of the inventor of this process—whose long experience in handling various water gas processes, indicated the value of a process that would eliminate these wasteful elements from its manufacture.

In this process, the generator and superheater are connected by a horizontal flue, which conducts the crude water gas from the generator through a descending flue in the side of the superheater, and delivers it into the main body of the superheater. Within this connecting flue—or carburetting chamber, as it is called—is an inclined table of fire-clay material, extending from the outlet opening in generator through to the descending flue in superheater. The oil is fed through the usual apparatus upon this inclined table and is there vaporized by the heat thereof, and mingling with the highly heated gases from the generator, is carried forward through the superheater, being thoroughly comingled and converted into fixed gas in its passage through the heated interior of that apparatus.

It will be seen that by this arrangement of apparatus the coal in the generator is entirely relieved of the work of vaporizing the oil, and is given only the duty of converting the steam into its constituent gases, while the fire-brick lining and inclined table of the carburetting chamber receive the oil and convert it into gas in the presence of the hot gas from the generator, by aid of heat absorbed during the usual process of heating up the coal by the air blast. The results obtained by this apparatus demonstrate the soundness of the theory of its inventor, as the runs are longer and the blowing-up periods shorter than in other cupola apparatus. The oil is not wastefully converted into lampblack at the first of the run, nor simply into condensable vapor at the last, but is evenly distributed and converted into gas throughout the entire run, making a saving of value in the quantity of enricher used per 1,000'. The economy in coal is equally marked, since the wasteful process of reheating the coal by blasts is less frequent and the active duty of the coal in each run much increased.

Practical working in a number of gas works situated in different parts of the country substantiate the claims made for this process, and records made in these several works prove, that a lower proportion of coal and oil is necessary per thousand cubic feet of commercial gas than has heretofore been used in any of the cupola processes.

GASHOLDERS AND TANKS.

Gasholders, and the tanks containing them, represent about 20 per cent. of the value of the plant. Aside from this, on their stability depends the safety of the community from sudden darkness, and the trouble arising from such a calamity. There can be no question as to the wisdom of building them in the most substantial manner.

The holders should be capable at the least, of containing 24 hours' maximum production of gas, and more, if the consumption is liable to sudden increase. The gasholder being a storage warehouse of a company, great care should be taken that it is not leaky, as many small leaks are equal to one large one, and such leakage goes on continually. The top of an exposed holder should be kept clear from snow as it falls.

Formerly it was the custom to build all holders with a curved roof or dome, supported by trussing. The majority of holders are now built perfectly flat and entirely without framing, the roof being built on a wooden platform erected for the purpose, and removed at the completion of the holder.

As the whole weight of the crown in a non trussed holder is supported by the curb, this portion of the frame must be made strong enough to sustain it. For the smaller sized holders the curb is made of two rings of angle iron and circular flat plates, secured to the angle irons with rivets and stay bolts, placed at short intervals around the curb. In larger holders the curb is made with channel irons and circular flat plates, forming a circular box girder around the edge of upper section. The center plates of crown are made about the same thickness as the circular flat plates of curb, the intermediate crown plates being made much lighter.

On the crown of holders, placed directly over the stand pipes are bonnets, for the protection of that part of the crown when down. The top plates are secured with tap bolts so that they can be easily removed.

The sides of upper section of holders are strengthened with vertical legs of beam or angle irons, according to the size of holder.

The hydraulic cups and grips are made of channel irons bent to the required radius, and the joints secured with heavy butt plates.

The proper working of a gasholder is helped by having the required number of columns or supports. Grooved guide wheels should be placed on the top of both upper and lower sections.

For ordinary single and double lift holders the tuscan columns have come into almost general use, but for very high holders they are so much out of proportion that they look absurd.

For a three lift holder, or for a double lift of extreme height, lattice columns, made with channel irons and flat iron, look the best and are fully as serviceable.

The tuscan columns referred to above are made of plate iron, in sections about 6 feet long, secured to each other with butt plates and countersunk rivets and cast iron caps and bases; the latter being secured to piers of tank with long anchor bolts built into the piers.

The number of columns necessary to properly support a holder is determined by the diameter of upper section: one column being allowed to every 10 ft. in diameter.

The above proportion of the number of columns to diameter gives a greater support to the holder and divides the wind pressure among a greater number of supports, giving greater steadiness of pressure.

It also makes the lattice guides of convenient lengths for handling, and admits of the angle iron chords being rolled in single lengths.

The following table of percentages has been made from the estimated weights and pressures of ten telescopic double-lift holders of the following dimensions :

***TELESCOPIC GASHOLDERS.—COMPUTED FROM THE ESTIMATED WEIGHTS OF 10 HOLDERS IN ACTUAL USE.**

GENERAL DIMENSIONS OF THE HOLDERS.

HOLDER.	DIAM. OF UPPER SEC.	DEPTH OF SIDE.	NO. OF COLUMNS.
No. 1	94 ft. 0 ins.	25 ft. 0 ins.	8
2	98 " 6 "	26 " 0 "	8
3	100 " 0 "	25 " 0 "	10
4	100 " 6 "	28 " 6 "	10
5	106 " 6 "	26 " 0 "	10
6	110 " 6 "	24 " 0 "	10
7	120 " 0 "	28 " 0 "	12
8	122 " 0 "	30 " 0 "	12
9	134 " 0 "	28 " 0 "	12
10	148 " 0 "	30 " 0 "	14

*From a paper read before the Society of Gas-Lighting by Wm. Mooney.

GENERAL TABLE OF WEIGHTS AND PERCENTAGES OF
TELESCOPIC GASHOLDERS.

	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
	Total Weight.	Per-centage.	Total Weight.	Per-centage.	Total Weight.	Per-centage.	Total Weight.	Per-centage.	Total Weight.	Per-centage.
	lbs.		lbs.		lbs.		lbs.		lbs.	
Upper section.....	115,315	32.88	147,914	34.06	143,172	33.83	149,856	37.25	164,585	35.97
Lower section.....	54,239	15.46	61,533	14.18	54,462	12.87	66,183	16.45	65,818	14.38
Columns.....	122,864	35.02	153,580	35.36	155,580	36.75	123,344	30.66	153,580	33.57
Ladder.....	615	.17	615	.15	590	.15	615	.15	615	.14
Girders.....	23,744	6.77	27,850	6.41	27,200	6.43	27,280	6.79	30,110	6.58
Chains and rods.....	2,512	.72	3,160	.72	3,080	.71	2,741	.69	3,160	.69
Counterweights.....	24,000	6.85	30,000	6.91	30,000	7.09	24,000	5.97	30,000	6.56
Wall plates and bolts.....	7,504	2.13	9,620	2.21	9,160	2.17	8,208	2.04	9,620	2.11
Total weight.....	350,793	100.00	434,292	100.00	423,244	100.00	402,230	100.00	457,488	100.00
Wrought iron.....	271,321	77.35	335,912	77.33	320,604	75.75	321,870	80.03	359,108	78.50
Cast iron.....	79,472	22.65	98,380	22.67	102,640	24.25	80,360	19.97	98,380	21.50
Maximum pressure.....	43.059 tenths.		48.093 tenths.		43.73 tenths.		49.091 tenths.		45.70 tenths.	

TABLE.—CONTINUED.

	No. 6.		No. 7.		No. 8.		No. 9.		No. 10.		Average.
	Total Weight.	Per-centage	Total Weight.	Per-centage	Total Weight.	Per-centage	Total Weight.	Per-centage	Total Weight.	Per-centage	
	lbs.		lbs.		lbs.		lbs.		lbs.		
Upper section.....	168,185	33.54	207,292	35.89	213,412	35.44	235,858	38.16	336,718	41.50	35.85
Lower section.....	65,489	13.06	85,902	14.87	88,751	14.75	95,665	15.51	123,846	15.26	14.67
Columns.....	188,424	37.57	197,392	34.26	208,284	34.58	195,492	31.70	240,198	29.60	33.90
Ladder.....	590	.12	656	.11	685	.12	656	.10	685	.08	.13
Girders.....	29,352	5.86	33,848	5.77	35,400	4.88	37,164	6.02	40,992	5.05	6.16
Chains and rods.....	3,624	.72	4,164	.72	4,404	.74	4,236	.69	5,138	.63	.71
Counterweights.....	36,000	7.17	36,000	6.23	33,000	5.97	36,000	5.84	46,200	5.70	6.44
Wall plates and bolts.....	9,792	1.96	12,216	2.11	15,210	2.52	12,216	1.98	17,752	2.18	2.14
Total weight.....	501,456	100.00	577,470	100.00	602,152	100.00	616,787	100.00	811,529	100.00	100.00
Wrought iron.....	377,448	75.27	439,970	76.18	461,632	76.66	484,415	78.54	649,395	80.02	77.56
Cast iron.....	124,008	24.73	137,500	23.82	140,520	23.34	132,372	21.46	162,134	19.98	22.43
Maximum pressure.....	42.06 tenths.		45.96 tenths.		46.97 tenths.		42.803 tenths.		48.644 tenths.		45.61

The weights of inlet and outlet pipes are not included in the above table.

To use the table of percentages, we must know the diameter and maximum pressure required. By squaring the diameter and multiplying the product by the pressure in tenths, and again multiplying this product by 0.40906, we have the weight of the holder in pounds, which can be divided among the several parts of the holder by the table. About 10 per cent. should be added for waste in manufacture, and an allowance made for the weight of water in cup.

NON-TRUSSED HOLDERS.

The proportion of weight of the crown of a "Non-Trussed Holder," bearing on a center point, will be about $\frac{1}{3}$ of the whole weight, if the iron is of uniform thickness throughout. It was found by experiment to be—

$$\frac{\text{Total weight of Crown}}{\text{weight on center point.}} = 3.1416$$

A recent writer in the London Journal of Gas Lighting—writing on the comparative cost of two and three lift holders, gives the following: In the first place the tank for the two lift holder will cost only about 20 per cent. more than for a three lift one; but the wrought iron guide framing for the three-lift holder will require to be nearly twice the strength of the framing of the two-lift.

There is 50 per cent. more leverage to take hold of the wind pressure in the three lifts; and the strength of structure to meet this must be carried throughout the greater height of framing and into all its details.

The net results of all the calculations for the two structures would be that the three-lift holder costs, when all things are fairly priced out, at least $12\frac{1}{2}$ per cent. more than the two-lift for the same capacity.

Going up into the air with structures conduces to neither economy of material nor to facile building. The area of sheeting plates or skin for gasholders is greater for three than for two lifts; taking the floating weight of a holder by itself, the sheeting alone amounts to more than one-half of the entire weight. Also the three-lifts have more complication in their construction, a greater number of parts, 50 per cent. more rollers and carriages to look

after and grease, and to be troubled with; a cranky, knock-kneed middle lift, with imperfect posts and stiffeners, as there is not room enough in the construction, nor space between the lifts to make repairs. The following table gives a detailed comparison of cost between the two-lift and three-lift holder.

TABLE.

COMPARING A TWO-LIFT HOLDER WITH A THREE-LIFT HOLDER,
INCLUDING TANKS, HOLDERS OF EQUAL CAPACITY.

No. 1.	No. 2.
Two-lift holder $\frac{H}{D} = 0.55$	Three-lift holder, $\frac{H}{D} = 1.0$.
Capacity, $6\frac{1}{2}$ million cubic ft.	Capacity, $6\frac{1}{2}$ million cubic ft.
Area of skin—side and crown, 147,612 square feet.	Area of skin (7 per cent. more than No. 1)=156,800 square feet.
Vertical sectional area, 32,819 square feet.	Vertical sectional area 40,000 square feet = 24 per cent. more than No. 1.
Stability, $32,819 \times 66 = 2,188,-$ 054.	Wind leverage = 50 per cent. more than No. 1, and nearly twice the strength of fram- ing.
Tank cost 20 per cent. more than for No. 2.	Stability,— $40,000 \times 100 =$ 4,000,000.
Land cost 33 per cent. more than for No. 2.	Area of base, 31,200 square ft.
Area of base, 46,058 square feet; 68 per cent. more than No. 2.	Excess of cost of tank and holder = $12\frac{1}{2}$ per cent.

The writer of the above shows his preferences for trussed roofed holders, and his dislike for non-trussed, or as he terms them *bladder topped* holders as follows: The trussed crown renders the structure self-contained for either storage purposes under a gale, or when under repair without inflation. The amount of wrought iron required for this special duty is only 6 per cent. of the total weight of framing and holder.

GASHOLDER TANKS.

The materials of which a Tank for a gasholder should be built, should be those most convenient, in some places stone would be cheaper than brick, and *vice versa*. In some parts of this country concrete tanks might be built ; and if well built, there is no reason why they should not answer every purpose. For a stone or concrete tank, iron bands would be necessary ; these should be placed about 5 feet apart, or perhaps somewhat closer near the bottom.

Brick being so abundant, and cheap ; in almost every portion of this country, that material is almost universally used, in the construction of tanks.

Owing to the fact that gas works are generally built near the water, the ground available for the tanks is sometimes made ground, or ground that has been reclaimed from the water by filling in with ashes, rubbish, &c.

On such ground, pile foundation is perhaps the safest, but it is dangerous to have one portion of the tank built on piles, and another portion on the solid ground, this would almost surely result in an unequal settlement.

Timbering and flooring on top of the piles is not necessary. The tops of the piles should be cut off to a general level below the water, and a bed of concrete from 18 inches to 3 feet thick placed upon them, extending at least one foot beyond the line of walls.

In tanks built on good compact natural ground, it is customary to leave a truncated cone in the center. This saves a great deal of expense in excavation, and is no disadvantage to the tank.

When a tank is built on wet ground, either from springs or tide water, a well must be sunk below the level of underside of concrete, and the water drained into it, from which it must be removed by pumping or otherwise. In some cases, where such well is fed by springs, it is afterward used as a water supply for the works, care being taken that the tank is perfectly tight, so that no foul water runs into the well.

Where the water is troublesome and inclined to break through the concrete bottom of tank, relief valves are built in, which at first, as the pressure of water is greatest from the outside, allow it to enter, but as the water rises in the tank, the increased pressure keeps them closed.

The inlet and outlet pipes should be made very strong, put together in the best manner and well bedded in the concrete. Arches should be turned over the horizontal pipes where they pass through the wall, and the space around them packed with clay or cement, so that the weight of the wall may not rest on them.

The horizontal pipes should be cast extra heavy with flanged joints, with heavy foot plates to the bends.

The concrete bottom of a tank built on ordinary ground should be at least 12 ins. thick, well rammed down, and neatly rounded at the angles of the cone.

The line of wall should be laid out by means of a radial bar, with an iron center pin permanently fixed at central point. templates are also generally used for keeping the circle true, and the work is plumbed at fixed points at equal distances around the inside of wall, the points taken being those to be finally used for the guide rails.

The actual strength of walls of tanks, necessary to resist the water pressure, has generally been ascertained from practice, and not from any theoretical calculations. As a general rule, for tanks over thirty feet in diameter, the top of wall should be two feet thick, (varying a little according to the brick used) and increased one brick (about 4 ins.) at every five to six feet in depth. In a tank say one hundred and fifty feet dia. by thirty feet deep, this would give a thickness of wall at the bottom of about three feet eight inches. Such a tank is assumed to be nearly or wholly below the ground level. The piers for the columns, should also be built with offsets following those of walls, except in extraordinary good ground where they may be carried up with one or two offsets only. None of the walls should be carried up more than four feet in advance of any other part. The bricks should be laid wet, and every joint completely filled with mortar, the template being used at every course. Every sixth course should be a bonding course, and no half bricks, or soft bricks to be used for any purpose.

After the holder is erected, and the scaffolding removed from the tank, (if it be removed,) the concrete bottom should have a layer of cement mortar three-quarters of an inch thick, over the entire surface, neatly trowelled off and left to dry for at least 10 days, or more if necessary. The inside of wall should also have a wash of pure cement, before the erection of the holder.

The walls of tank should be allowed to dry slowly, before filling with water, and the filling should be done very slowly. A new tank will absorb a large quantity of water, when first filled before the pores in the brick and cement are filled.

The earth filling behind walls, is a part of the works of as great importance as the building of the walls themselves, as the sustaining power of the back filling is an important element of strength. In England it seems to be the custom to fill in behind walls with a puddle of clay, but this is rarely, if ever done here.

In regard to this matter of puddling, the author of Richards' treatise says: "The opinion of the inutility of puddle for the purpose (backing of walls) was forced upon the writer by circumstances, for having to construct a brick tank in a locality where the requisite clay was not to be had, decided on dispensing with it, and the success which attended the experiment, was sufficient to prove the use of puddle absolutely unnecessary. From that period * * * puddle has never been employed by us, nor have we had reason to regret its absence."

The earth should be wet as it is thrown behind the walls, and every shovelful well rammed down. If the walls of tank are raised above the general level, the earth should be banked up for a distance of at least 10 feet from the inside line of walls, and this earth should also be well and thoroughly rammed down. A suitable outlet or overflow pipe should be built in wall just under coping.

The footing or landing stones for holder, should stand about 8 or 12 ins. above bottom of tank, and are generally 12 by 12 by 30 ins. Care should be taken that all these stones are placed at the same level on top.

The coping should extend entirely over top of walls and piers, the coping to be axed with radial joints.

The cement mortar for walls and the concrete for foundations should be made as follows:

CEMENT MORTAR.—One part of the best fresh hydraulic cement.

Two " " clean sharp sand.

CONCRETE.—One part of best fresh hydraulic cement.

Three " " clean sharp sand.

Four " " broken stone.

SPECIFICATION of the materials and works required in building and completing a Tank for a Gas Holder for the _____ Gas Light Co. of _____ according to the accompanying plans, sections, details, &c., annexed and the conditions subjoined.

The Tank to be one hundred and fifty-two feet in diameter and thirty-one feet six inches deep, at the sides.

EXCAVATION.—Remove and cart away from the whole of the plot, all of the rock, soil, rubbish and useless material. Excavate for the Tank and stand pipes, according to the area marked on the plans, and to the depth necessary to bring the top of coping—of tank to the desired level.

The ground to be left in center of tank, in the form of a low truncated cone, to be made perfectly true, cylindrical and solid, and to be well rammed down, where the original soil has been disturbed.

The sides of Excavation to be shored up where necessary, and the shores maintained so as not to interfere with the work.

After the brick work of Tank has been properly seasoned, and the stand pipes set, refill and ram down and fill up to the level of underside of coping of Tank.

At the completion, remove and cart away from the premises all the dirt, rock and rubbish of every description leaving the plot in perfect order. The earth used for filling in against walls must be wet, and every shovelful well rammed down.

DRAINAGE.—Draw off, pump away and remove all water and soil that may come into the excavation from springs, rivers, ponds, sewers, canals, tanks, cesspools, rain or from any other cause, and effectually complete the drainage, before any of the concrete or brick work is done.

Should there be any excess of water in the excavation, a well must be sunk, and the drainage conducted into it, from which it must be pumped, so that the water shall be kept at all times below level of bottom of concrete.

CONCRETE.—The stones for the concrete shall be of the best quality, perfectly free from dirt, loam or other impurities, and the surfaces to show a clean fracture.

The whole of the stones to be broken into such sizes, as will pass through a circular ring of iron two inches in diameter.

The concrete to be compounded as follows :

One cask of the best hydraulic cement.

Three casks loose of clean sharp sand.

Five " of clean broken stone or brick.

The whole to be thoroughly mixed together in the most careful manner, and water to be added to so much of the mixture as can be used at once. The whole of the concrete to be laid down in these layers and well rammed.

The vertical and horizontal pipes will be provided and erected by the Gas Co., but the contractor for the Tank shall carefully bed and secure the pipes in the concrete. None of the concrete that has been allowed to set or become dead must be remixed and used, but must be at once rejected.

CEMENT MORTAR.—The whole of the mortar used in laying the bricks to be made in the best manner and compounded as follows :

One cask of best hydraulic cement.

Two " (loose) of clean sharp sand.

The mortar for plastering the outside of walls to be compounded as follows :

One cask of the best hydraulic cement.

One and a half casks (loose) of clean sharp sand.

BRICK WORK.—The whole of the bricks shall be sound, hard burned, uniform in size, and of the best quality, free from broken brick, clinkers, &c.

The brick work to be commenced on the top of the concrete, after it has properly set and hardened.

The bricks to be laid wet and every sixth course to be a heading course. Every course to be well grouted with liquid cement leaving no interstices or empty spaces in the walls.

The joints on the outer sides of walls to be left rough, for plastering, and the inside joints of walls to be neatly pointed.

The tank walls to be plumbed at stated points not more than 15 feet apart.

The tank when finished to be perfectly cylindrical, true, and the walls plumb on the inner side.

Four vertical holes 4 by 4 inches, shall be built into each of the piers to receive the anchor bolts of columns.

An opening to be made at the bottom of each hole for the purpose of putting on the nuts and washers.

The said openings to be filled in solid after the bolts are in place.

Provide and build in the walls of tank; where directed by the Engineer, four complete rings of iron 3 by $\frac{3}{16}$ ins. securely bolted together with $\frac{1}{2}$ inch bolts.

STONE WORK.—Provide and set the coping of tank and pier caps to piers, as per drawing. Coping to be six inches thick and pier caps 12 inches thick, with holes cut for bolts. The coping and pier caps to cover the whole of the brick work exposed to the weather. The coping and pier caps to be axed. The coping to have radial joints and the inner and outer edges cut to the proper radius.

Coping on center pier as per drawings. Twenty-eight, axed footing stones 12 by 12 by 30 inches to be provided and set on concrete bottom of tank, at equal distances all around, and the tops to be perfectly level and in line.

PLASTERING.—The whole of the outer side of tank walls, extending from concrete to coping to have one coat of plastering $\frac{1}{2}$ inch thick.

The whole of the work to be done in the best and most workmanlike manner, and the tank to be made perfectly water tight.

The whole of the work to be done under the general direction and to the entire satisfaction of the Engineer of the Co.

(For Conditions and form of Contract See Appendix).

SPECIFICATION of the materials and works required, in constructing, erecting, and completing a Telescopic Gasholder for the _____ Gas Light Co. of _____ according to the accompanying plans, elevations, and sections, annexed, and the conditions subjoined.

INNER OR UPPER SECTION.

DIMENSIONS.—The inner or upper section of the holder to be one hundred and forty-eight feet in diameter, and thirty feet deep on the side.

CROWN.—The crown to be formed without trussing or framework, and to be built perfectly flat, and level on a temporary scaffolding prepared for the purpose.

CURB.—The top curb to be curved to a radius of seventy-four feet, on the outer edge, and to be constructed of two rows or rings of circular flat plates, two rows or rings of angle iron, and one row or ring of channel iron, as per detail drawings.

The upper circular plates to be fifteen inches wide by one-half inch thick, the lower circular plates to be twelve and three-quarter inches wide by one-half inch thick, and the whole to be curved to the proper radius.

The angle iron for the two rows or rings of curb to be six inches by four and one-half inches, and to weigh not less than eighteen and one-half pounds per running foot.

The channel iron to be nine inches by two and three-quarter inches, and to weigh not less than twenty-three and one-third pounds per running foot.

The whole of the circular plates, angle and channel irons, to be placed so as to break joints with each other.

The whole of the joints of curb, to be secured with butt plates twenty inches long.

The butt plates for the circular flat plates to be four inches wide, and three-eighths inch thick.

The butt plates for the angle irons to be formed of flat iron nine inches wide, and five-eighths inch thick, bent to fit the inner side of angle irons.

The butt plates of the channel irons to be each nine inches wide by one half inch thick, and secured to the channel iron with six three-quarter inch rivets, and six three-quarter inch tap bolts.

The upper circular plates to be secured to the upper angle iron of curb with two rows of three-quarter inch rivets, and to the channel iron with one row of three-quarter inch rivets, placed two and a half inches from centers.

The lower circular plates to be secured to the lower angle iron of curb with two rows of three-quarter inch rivets, and to the channel iron with one row of three-quarter inch rivets.

The rivets in each row in the angle iron to be placed five inches from center to center, and in the channel iron, two and one-half inches from centers.

The curb to be secured to each of the ten and one-half inch vertical legs or ribs with two pieces of four by four inch angle irons, and nine three-quarters inch rivets, and to each of the eight inch vertical legs or ribs, with three pieces of angle iron and ten three-quarter inch rivets.

CROWN PLATES—The center plate of crown to be three-eighths of an inch thick, and five feet in diameter—weighing not less than fifteen lbs. per square foot.

The plates for the first, second, third and fourth rows from the center to weigh not less than ten and four-tenths lbs. per square foot, and to be secured to the center plate, and to each other with seven-sixteenth inch rivets placed one and a half inches from center to center, and the first row of plates to be secured to the center plate with two rows of said rivets.

The plates for the fifth, sixth, seventh and eighth rows from the center to weigh not less than seven and twenty-four one-hundredths lbs. per square foot, and to be secured to the fourth row, and to each other with three-eighth inch rivets, placed one and one-quarter inches from centers.

The plates for the ninth, tenth, eleventh and twelfth rows to weigh not less than four and eighty-three one hundredths lbs. per square foot, and to be secured to the eighth and thirteenth rows, and to each other with five-sixteenth inch rivets placed one inch from centers.

The thirteenth row of plates, to weigh not less than seven and twenty-four hundredths lbs. per square foot, and to be secured to the half inch circular plates of curb, with two rows of three-eighth inch rivets, and to each other with one row of said rivets, placed one and one quarter inches from centers.

MANHOLES.—Two manholes, with frames, covers and tap bolts to be placed near the outer edge of the holder.

BONNET.—A bonnet thirty-six inches in diameter, and eighteen inches high, to be placed directly over the center of stand pipe. Said bonnet to be made with two rings of angle iron two and three-quarters by two and three-quarters by five sixteenth inches, side sheets weighing not less than four and eighty-three hundredth lbs. per square foot, and covering plate weighing not less than ten and four-tenths lbs. per square foot. The lower angle iron to be secured to the crown plates of holder, and side sheets of bonnet, with five-sixteenth rivets placed one inch from centers.

The upper angle iron to be secured to the covering plate with half inch bolts placed not more than two and one-half inches from centers, and to the side sheets as directed for lower angle irons.

SIDE SHEETS.—There shall be twelve rows of sheets on the side of upper section.

The top row of sheets to be twenty-eight inches wide from center to center of rivets, to weigh not less than ten and seven one-hundredths lbs. per square foot, and to be secured to both the angle irons forming top curb with two rows of five-eighth inch rivets placed two and one-half inches from centers, and to each other with half inch rivets placed two inches from centers.

The bottom row of sheets to be twenty-eight inches wide, from center to center of rivets, to weigh not less than seven and five-tenths lbs. per square foot, to be secured to the angle iron of cup and to each other with three-eighth inch rivets placed one and one-quarter inches from centers.

The whole of the intermediate sheets to be thirty inches wide from center to center of rivets, to weigh not less than three and thirty-four hundredths lbs. per square foot, to be secured to the top and bottom plates with five-sixteenth inch rivets, and to each other with one-quarter inch rivets placed one inch from centers.

VERTICAL LEGS.—The sides of the upper or inner sections to be strengthened with twenty-eight legs of beam iron, each twenty-nine feet ten inches long by ten and one-half inches wide, weighing not less than thirty-five lbs. per running foot. Also twenty-eight legs of beam iron each twenty-nine feet long by eight inches weighing not less than twenty-two lbs. per running foot.

The twenty-eight legs of ten and one-half inch beam iron to be trussed, and placed opposite the barrel rollers, and the remaining legs to be placed opposite and between the columns, as per drawings.

Each of the said legs of beam iron to be secured to the side of holder and outer vertical strips with two rows of $\frac{5}{8}$ inch bolts and washers, and the bolts in each row to be placed ten inches from centers. The rods for trussing the legs to be one inch in diameter, and well secured at each end with four five eighth inch bolts, and in the center of each rod there shall be a union with the screw ends enlarged to $1\frac{1}{4}$ inches in diameter.

VERTICAL OUTER STRIPS.—On the outer side of the upper section there shall be placed opposite the inside vertical legs of $10\frac{1}{4}$ inch beam iron twenty-eight vertical plates or strips, six inches wide by one-half inch thick, and thirty feet long, to be secured to

the side plates, and inside vertical legs with two rows of $\frac{3}{8}$ inch bolts and washers, and the bolts in each row to be placed ten ins. from centers. The vertical strips to be braced on top of upper section with angle irons of suitable size.

HYDRAULIC CUP.—The hydraulic cup to be eight inches wide by fifteen inches deep, and formed with two rows of angle irons $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ inches, weighing not less than six lbs. per running foot, and the bottom plate eight inches wide by $\frac{3}{8}$ inch thick

The butt joints to be placed at equal distances apart, so that every piece shall break joint with the one opposite.

The outer plates to weigh not less than seven and one-half lbs. per square foot, and to be riveted to the angle iron and to each other with $\frac{3}{8}$ inch rivet, placed one and one-quarter inches from centers.

The bottom plates of the cup to be secured to the angle iron with $\frac{3}{8}$ inch rivets placed two inches from centers.

The upper edge of the cup to be strengthened with two rings of 2 by 1 inch bead iron, as per drawings, riveted with $\frac{3}{8}$ inch rivets placed three inches from centers. The joints of the bead iron to be lapped, and to be so placed as to break joints with each other.

The inside of bottom of cup to have fifty-six bearing pieces, two and one-half inches wide by one-half inch thick and eight inches long, placed at equal distances around the cup.

CARRIAGE ROLLERS.—On the under side of cup there shall be fixed twenty-eight turned barrel rollers, with suitable carriages, to work against the vertical channel irons on inner side of lower section of holder. Each roller and carriage to be secured to the bottom of cup with four $\frac{3}{4}$ inch bolts, and to the flanges of vertical legs with $\frac{3}{4}$ inch bolts and washers.

OUTER OR LOWER SECTION.

DIMENSIONS.—The outer or lower section of holder, to be one hundred and fifty feet in diameter, and thirty feet deep on the side.

SIDE SHEETS.—The side sheets of lower section will be twelve in number. The top and bottom rows of sheets to be each two feet eight inches wide, from center to center of rivets, and to weigh not less than seven and one-half lbs. per square foot.

The top row of plates to be secured to the angle iron of cup and to each other with $\frac{3}{8}$ inch rivets placed one and a quarter inches from centers. The bottom row of plates to be secured to each of the angles forming the bottom curb, with $\frac{1}{2}$ inch rivets placed two and a half inches from centers, and to each other with $\frac{3}{8}$ inch rivets placed one and one quarter inches from centers.

The intermediate rows of sheets to be thirty inches wide from center to center of rivets, and to weigh not less than three and $\frac{34}{100}$ lbs. per square foot, to be secured to the top and bottom rows of plates, with $\frac{5}{16}$ inch rivets, and to each other with one quarter inch rivets, placed one inch from centers.

BOTTOM CURB—The bottom curb of lower section to be formed of two rows or rings of angle iron 8 by 4 inches, each weighing not less than $10\frac{1}{2}$ lbs. per foot, and curved to a radius of seventy-five feet on the inner side. All the butt joints to be placed at equal distances apart, so that every piece shall break joint with the piece opposite. The whole of the butt joints to be secured with plates 20 inches long, and two rows of $\frac{5}{8}$ inch rivets placed two and one-half ins. from centers. The butt plates to be of the same section and area as angle iron. Half inch stay bolts cased in tubes to be placed twenty four inches from centers all around the bottom curb.

INVERTED CUP.—The inverted cup to be eight inches wide and fifteen ins. deep, and to be made similar to the hydraulic cup on upper section of holder.

ROLLERS.—On the top of inverted cup, there shall be fixed twenty-eight turned barrel rollers with suitable carriages—to work against the vertical strips on upper section, and fourteen turned and grooved rollers, with adjustable carriages to work against the guide rails on columns.

On the bottom curb of lower section there shall be fixed twenty-eight turned barrel rollers with suitable carriages, to work against the guide rails on walls of tank—and each to be secured to the angle irons with $\frac{3}{4}$ inch bolts.

VERTICAL BARS OF CHANNEL IRON.—On the inside of outer or lower section there shall be fixed fifty-six vertical bars of channel iron, $1\frac{1}{2}$ by 5 inches, each weighing not less than 11 lbs. per

foot. Each of the said bars to be rolled in one length—and secured to the side sheets with two rows of half inch bolts, and malleable iron washers. Bolts to be placed 10 inches from centers, with heads sunk and made flush with face of bar.

CHAINS.—Provide and attach to the cross bars of suspension rods that carry the lower section, and to the balance weights in the columns—fourteen $\frac{5}{8}$ inch chains, each 60 feet long.

SUSPENSION RODS—On the outer edge of the lower section and opposite to the columns there shall be fixed fourteen sets of suspension rods, with strong cross bars on top—each to be $\frac{1}{2}$ inch dia. and securely fixed to the holder,

BALANCE WEIGHTS.—Provide and fix securely to the cable in each column, a counterweight containing thirty-three hundred lbs. of metal, to counterbalance the lower section of holder.

COLUMNS.

There shall be fourteen columns, constructed as per drawings.

BASES, CAPS, AND ENTABLATURES.—The bases, caps, and entablatures to be made of cast iron and the seats for the wrought iron shafts to be turned in lathe.

SHAFT.—The nine intermediate sections between cap and base to be made of wrought iron—with planed and turned joints, to be riveted to the caps and bases, and to each other with $\frac{1}{2}$ inch rivets, placed 4 inches from centers.

The holes on the outer side of shaft to be countersunk and the heads of the rivets made flush with the plates.

The wrought iron plates for the three lower sections of shaft to weigh not less than sixteen lbs. per square foot, the three upper sections to weigh not less than 11 lbs per square foot, and the three intermediate sections to weigh not less than twelve and one-half lbs. per square foot.

Each section to be formed and made in one whole plate, and one vertical joint. The vertical joints in each column to be placed in line, and to face the guide rails.

The joints or butt plates to be each six inches wide by $\frac{1}{2}$ inch thick.

GUIDE RAILS—Guide rails to be fixed on all the columns, and constructed as per drawings.

WHEELS.—A turned and grooved wheel to be fixed in the entablature on each of the columns.

BOLTS.—Each of the columns to be secured to the stone, and brick work of tank, with five holding down bolts, each ten feet long between the two nuts, and two inches in diameter.

WASHERS.—Cast iron washers to be made for all the lower ends of holding down bolts each 12 by 12 by 2 inches.

The whole of the said bolts, nuts, and washers to be provided and delivered at the tank within — weeks after signing contract.

GIRDERS.

The columns to be connected together at the top, with fourteen wrought iron girders each thirty-two feet one and one-half inches long and three feet deep. Each end of the girders to be secured to the entablature with twelve $\frac{1}{4}$ inch bolts, and to the cap on columns with five one inch bolts.

Each of the angle irons for top and bottom chords of girders to be rolled in one length, so as not to require any butt joints or plates between the two ends.

LADDER.—A wrought iron ladder to be properly secured to one of the columns, and placed where directed by the Engineer. The sides of the ladder to be 3 by $\frac{1}{4}$ ins. by fifty-eight feet long. Steps to be $\frac{1}{4}$ inch diameter and 14 ins. long, placed 12 ins from centers.

WALL PLATES.—Twenty-eight sets of wall plates attached to walls of tank. To be of heavy railroad iron, and to be placed perfectly vertical and at equal distances around tank walls.

The holder and frame to be built in the most substantial and workmanlike manner, and to be made perfectly gas and air tight.

The joints in the holder to be well secured with red lead and linseed oil, and caulked where necessary.

The edges of the plates to be cut fair, true and in line with the rivets.

The whole of the iron work of frame and holder, both inside and outside of holder, to have one coat of the very best red lead and linseed oil, before leaving the works of the Contractor.

(For Conditions and Form of Contract See Appendix.)

RIVETING FOR GASHOLDER PLATES.

SINGLE ROW.				DOUBLE ROW				
Size of Rivet.	Thick. of Plate	Lap.	Dist'nc Apart.	Size of Rivet.	Thick. of Plate	Lap.	Dis. from centres in Line.	Dis from centres Tr'nsv'rs
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
$\frac{1}{8}$	$\frac{1}{8}$	1	1	$\frac{1}{8}$	$\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$
$\frac{5}{16}$	$\frac{5}{16}$	1	1	$\frac{5}{16}$	$\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$\frac{3}{4}$
$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{7}{8}$
$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{8}$	$2\frac{1}{2}$	2	1
$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{1}{2}$
$\frac{9}{16}$	$\frac{9}{16}$	2	2	$\frac{9}{16}$	$\frac{9}{16}$	$3\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$
$\frac{5}{8}$	$\frac{5}{8}$	2	2	$\frac{5}{8}$	$\frac{5}{8}$	$3\frac{1}{4}$	$2\frac{3}{4}$	$1\frac{3}{8}$
$1\frac{1}{8}$	$1\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$3\frac{3}{4}$	3	$1\frac{1}{2}$
$\frac{3}{4}$	$\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$4\frac{1}{4}$	$3\frac{1}{4}$	$1\frac{3}{4}$
$1\frac{3}{8}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$4\frac{1}{2}$	$3\frac{3}{4}$	2
$\frac{7}{8}$	$\frac{7}{8}$	3	3	$\frac{7}{8}$	$\frac{7}{8}$	5	4	2
$1\frac{5}{8}$	$1\frac{5}{8}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$5\frac{1}{4}$	$4\frac{1}{2}$	$2\frac{1}{4}$
1	$\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	1	$\frac{1}{2}$	$5\frac{3}{4}$	$4\frac{3}{4}$	$2\frac{1}{2}$

TABLE OF THE WEIGHTS OF GASHOLDERS.

IN POUNDS FOR EVERY ONE-TENTH OF AN INCH MAXIMUM PRESSURE, AND FROM 20 TO 256 FEET IN DIAMETER.

Diam. of Gas-holder in ft.	Wgt. in lbs. each 1-10th of an in. pres.	Diam. of Gas-holder in ft.	Wgt. in lbs. each 1-10th of an in. pres.	Diam. of Gas-holder in ft.	Wgt. in lbs. each 1-10th of an in. pres.	Diam. of Gas-holder in ft.	Wgt. in lbs. each 1-10th of an in. pres.	Diam. of Gas-holder in ft.	Wgt. in lbs. each 1-10th of an in. pres.	Diam. of Gas-holder in ft.	Wgt. in lbs. each 1-10th of an in. pres.
20	164	60	1473	100	4091	140	8018	180	13254	220	19798
21	181	61	1522	101	4173	141	8133	181	13461	221	19979
22	198	62	1573	102	4256	142	8249	182	13549	222	20160
23	217	63	1624	103	4340	143	8366	183	13699	223	20332
24	236	64	1676	104	4425	144	8483	184	13849	224	20525
25	257	65	1729	105	4510	145	8601	185	14000	225	20709
26	277	66	1782	106	4597	146	8720	186	14152	226	20893
27	298	67	1837	107	4684	147	8840	187	14365	227	21079
28	321	68	1892	108	4772	148	8961	188	14458	228	21264
29	344	69	1948	109	4861	149	9083	189	14612	229	21449
30	368	70	2005	110	4950	150	9205	190	14767	230	21639
31	393	71	2062	111	5041	151	9327	191	14923	231	21828
32	419	72	2121	112	5132	152	9451	192	15080	232	22017
33	446	73	2180	113	5224	153	9576	193	15237	233	22207
34	473	74	2240	114	5317	154	9701	194	15395	234	22398
35	501	75	2301	115	5410	155	9828	195	15565	235	22591
36	530	76	2363	116	5505	156	9954	196	15715	236	22783
37	560	77	2426	117	5600	157	1008	197	15842	237	22977
38	591	78	2489	118	5696	158	1021	198	16037	238	23171
39	622	79	2553	119	5793	159	1034	199	16199	239	23366
40	655	80	2618	120	5891	160	10472	200	16364	240	23563
41	688	81	2684	121	5990	161	10603	201	16526	241	23759
42	722	82	2751	122	6089	162	10735	202	16691	242	23956
43	757	83	2818	123	6189	163	10868	203	16857	243	24154
44	792	84	2887	124	6290	164	11002	204	17023	244	24355
45	828	85	2956	125	6392	165	11136	205	17191	245	24554
46	866	86	3026	126	6495	166	11272	206	17359	246	24755
47	904	87	3097	127	6598	167	11408	207	17528	247	24956
48	943	88	3168	128	6703	168	11545	208	17697	248	25159
49	982	89	3241	129	6808	169	11683	209	17868	249	25362
50	1023	90	3314	130	6914	170	11822	210	18039	250	25566
51	1064	91	3388	131	7021	171	11961	211	18211	251	25772
52	1106	92	3463	132	7128	172	12102	212	18384	252	25977
53	1149	93	3538	133	7237	173	12243	213	18558	253	26184
54	1193	94	3615	134	7346	174	12385	214	18733	254	26391
55	1238	95	3692	135	7456	175	12528	215	18908	255	26599
56	1283	96	3770	136	7567	176	12671	216	19085	256	26808
57	1329	97	3849	137	7678	177	12816	217	19262		
58	1376	98	3929	138	7791	178	12961	218	19440		
59	1424	99	4010	139	7904	179	13107	219	19619		

To ascertain the weight of a Gasholder by the above table, the diameter and maximum pressure being known—

RULE.—Multiply the number of lbs. standing opposite to the diameter by the pressure in tenths of an inch.

EXAMPLE.—What is the weight of a gasholder 78 feet in diameter, giving a maximum pressure of $\frac{3}{8}$ ths ?

$2489 \times 32 = 79,648$ lbs. weight of gasholder.

To ascertain by the above table the pressure a gasholder will give, the weight and diameter being known—

RULE.—Divide the weight in lbs. of the gasholder by the weight given opposite to the diameter.

EXAMPLE.—What pressure will a gasholder give whose weight is 32,075 lbs. and diameter 56 feet ?

$$\frac{32,075}{1288} = \frac{3}{8}$$
ths maximum pressure of gasholder.

The figures given in the above table are based on the weight of a cubic foot of water; viz: 62.5 lbs. a column one-tenth of an inch high being .52083 lbs. or the 120th part.

Thus if the area of the holder in feet (obtained by squaring the diameter and multiplying by .7854) be multiplied by 62.5 the weight of a cubic ft. of water in lbs. and divided by 120 the number of tenths of an inch in one foot, the product will be the weight of the holder in lbs. for each one-tenth of an inch maximum pressure.

Or thus :—The area of a circle is to the square of its diameter as .7854 is to 1 ; hence the weight of a gasholder in lbs. to give one-tenth of an inch pressure is to the square of a diameter in feet as .52083 x .7854 is to unity ; or which is the same thing as .4091 is to unity. Therefor to ascertain the weight of a holder, say 100 feet in diameter giving a maximum pressure of $\frac{3}{8}$ ths.

$100^2 \times 35 \times .4091 = 143,185$ lbs. weight of gasholder.

CAPACITY OF CIRCULAR CISTERNS AND TANKS IN
GALLONS FOR EVERY FOOT IN DEPTH.

Diameter in ft.	Gallons per ft. Depth.	Diameter in ft.	Gallons per ft. Depth.	Diameter in ft.	Gallons per ft. Depth.	Diameter in ft.	Gallons per ft. Depth.
5	146.8	44	11373.4	83	40471.2	122	87439.7
6	211.4	45	11896.2	84	41452.0	123	88879.6
7	287.9	46	12431.0	85	42445.2	124	90330.7
8	376.0	47	12977.0	86	43449.8	125	91793.1
9	475.9	48	13535.0	87	44465.6	126	93268.1
10	587.5	49	14105.0	88	45494.1	127	94754.4
11	710.9	50	14686.9	89	46533.8	128	96251.6
12	846.0	51	15280.1	90	47585.5	129	97762.1
13	992.9	52	15885.2	91	48648.4	130	99283.5
14	1151.5	53	16501.6	92	49724.0	131	100817.0
15	1321.9	54	17130.7	93	50711.6	132	102362.3
16	1503.9	55	17770.9	94	51909.0	133	103919.6
17	1697.8	56	18423.2	95	53019.7	134	105487.4
18	1903.3	57	19086.7	96	54141.7	135	107068.7
19	2120.7	58	19762.1	97	55275.7	136	108659.7
20	2350.1	59	20450.3	98	56421.6	137	110263.4
21	2590.7	60	21149.0	99	57578.8	138	111879.1
22	2843.3	61	21859.5	100	58748.0	139	113496.7
23	3107.7	62	22582.1	101	60628.2	140	115145.6
24	3383.8	63	23316.6	102	61121.3	141	116796.4
25	3672.0	64	24063.1	103	62325.6	142	118459.2
26	3971.3	65	24820.8	104	63541.1	143	120133.2
27	4282.6	66	25590.5	105	64769.3	144	121819.2
28	4605.8	67	26371.4	106	66008.7	145	123517.2
29	4940.6	68	27164.3	107	67260.1	146	125227.1
30	5287.7	69	27969.2	108	68524.2	147	126948.3
31	5645.6	70	28786.0	109	69798.1	148	128681.4
32	6015.7	71	29614.8	110	71084.6	149	130425.7
33	6397.6	72	30454.8	111	72384.0	150	132182.8
34	6791.2	73	31306.0	112	73693.0	151	133951.8
35	7197.1	74	32169.9	113	75014.6	152	135730.5
36	7613.1	75	33045.1	114	76348.3	153	137522.8
37	8042.5	76	33932.2	115	77684.7	154	139326.2
38	8483.0	77	34831.3	116	79050.8	155	141141.6
39	8934.8	78	35741.6	117	80419.7	156	143019.0
40	9399.3	79	36663.9	118	81801.2	157	144817.5
41	9875.1	80	37598.2	119	83192.5	158	146658.1
42	10362.8	81	38544.4	120	84596.5	159	148520.6
43	10862.4	82	39501.8	121	86012.5	160	150394.6

The American standard gallon contains 231 cubic inches, or 8½ lbs. of pure water at its maximum density 39.83° Fah. and 30 ins. barometer. A cubic foot contains 62.3 lbs. of water or 7.48 gallons.

Pressure per square inch is equal to the depth or head in feet multiplied by .433. Each 27.72 inches of depth gives a pressure of one pound per square inch.

TO COMPUTE THE WEIGHT OF WATER, ONE FOOT IN DEPTH, IN
A CIRCULAR CISTERN OR TANK.

RULE.—Divide the number of gallons given in table by 7.48, and multiply the quotient by 62.5, the product will be the weight of water in lbs.

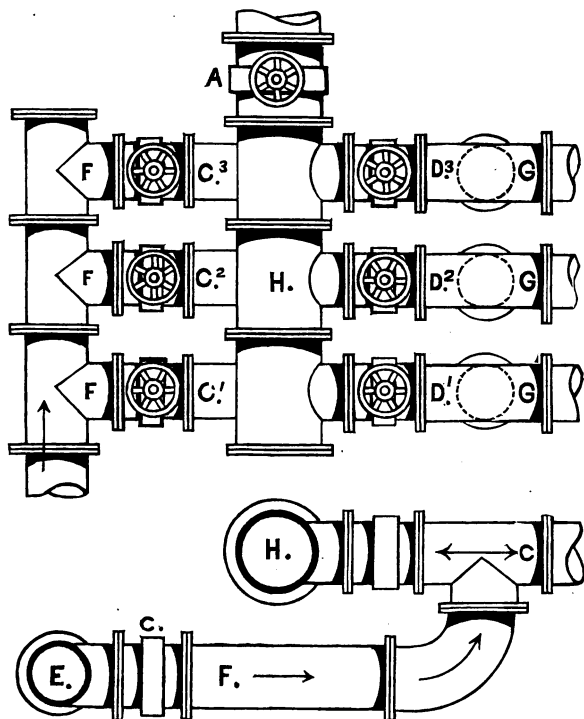
EXAMPLE.—Required the weight of water, one foot in depth,
in a tank 100 feet diam. $\frac{58748}{7.48} = 7854 \times 62.5 = 490,875$ lbs.

TO COMPUTE THE CAPACITY OF, AND WEIGHT OF WATER IN A
RECTANGULAR TANK.

The length, breadth and depth in feet multiplied together will give the cubic contents in cubic feet; this product multiplied by 62.5 will give the weight of water in pounds. The cubic contents multiplied by 7.48 will give the contents in gallons.

FARMER'S PIPE AND VALVE SYSTEM.

This simple arrangement of the valves controlling the gas-holders was first introduced at the old works of the Cincinnati Gas Light Co. when they were rebuilt in 1871. The valves previous to this change were scattered all over the works. By this plan one pipe serves as both inlet and outlet to each holder.



FARMER'S PIPE AND VALVE SYSTEM.

The sketch shows the valves and connections for three holders but any number above one can be arranged in the same manner.

The valves are placed in two parallel lines, the inlet valves on one side, and the outlet valves on the other, with the valve controlling the supply to the street mains at one end between them.

D is the inlet pipe through which all the gas from the works must pass in going into the holders. F F F are the inlet pipes through which the gas passes into the holders, connecting through bends underneath (see section) with the pipes G G G which are the inlet and outlet pipes to holders. H A is the main outlet pipe through which all the gas must pass to the street mains.

C¹ C² C³ are the inlet valves, D¹ D² D³ are the outlet valves, and A is the street valve, through which all the gas going into the street mains must pass.

By opening the valve C¹ the gas passes from the works into holder No. 1.

By opening the valve C² the gas passes from the works into holder No. 2.

By opening the valve C³ the gas passes from the works into holder No. 3.

The gas can also be passed into any two of the holders at one time while it passes from the remaining one into the street mains. By opening either of the valves D¹ D² D³ the gas passes into the main pipe H, which is controlled by the street valve A.

Two of the holders can also be connected with the street mains at one time, while the remaining one is being filled.

The greater the number of holders in use by this system, the greater appears its simplicity, as the valves can all be arranged in proper order, and in a very small room where one man can control them and can tell the condition of all the holder valves at a glance.

The valves have an indicator scale which rises and falls above the wheel as the valve is opened or shut, showing the exact position of the gate.

This system can be used with or without a governor, but should be connected with the usual pressure register, supplied with a card with the required pressure shown on it for the 24 hours.

Any deviation from this line will be shown on the register, and the cause for it can be investigated.

DETAILS AND DIMENSIONS OF GASHOLDERS IN ACTUAL SERVICE.

SINGLE LIFT HOLDER.

Diameter, 80 feet ; depth, 22 feet.

Working capacity, 105,000 cubic feet.

Crown, non-trussed.

Curb, 2 rows of angle iron 3 by 4½ ins. One row of circular flat plates, forming part of crown, 1 ft. 6 ins. wide and ¾ ins. thick.

Crown sheets.—Curb sheets as above, intermediate sheets $4\frac{4}{10}$ lbs. per square ft. Center sheet, 4 ft. diam. $\frac{3}{8}$ in. thick. Side sheets, top and bottom sheets $4\frac{4}{10}$ lbs. per square ft.

Intermediate sheets— $3\frac{2}{10}$ lbs. per square ft.

Bottom curb.—4 by 4 by $\frac{1}{2}$ in. angle iron.

Vertical legs.—16 vertical legs, 4 by 4 by $\frac{1}{2}$ in. angle iron, 8 columns, sheet iron shafts, cast iron caps and bases, 8 girders, angle iron top and bottom chords 3 by 3 by $\frac{1}{2}$ in., flat iron $2\frac{1}{2}$ by $\frac{1}{2}$ in.

Inlet and outlet pipes 12 in. diam.

—Built by DEILY & FOWLER,

Laurel Iron Works, Phila., Pa.

SINGLE LIFT HOLDER.

Diameter, 90 feet; depth, 40 feet.

Working capacity, 248,100 cubic feet.

Crown—non-trussed.

Curb.—Two rings of angle iron 6 by 4 ins., and one row of flat circular plates, 1 ft. wide by $\frac{5}{8}$ in. thick.

Crown sheets. Center plate.—6 ft. diam., $10\frac{1}{2}$ lbs. per square ft.

Intermediate sheets— $5\frac{1}{10}$ lbs. per square ft.

Curb sheets as above.

Side sheets, top and bottom row— $7\frac{1}{2}$ lbs. per square ft.

Intermediate sheets— $3\frac{2}{10}$ lbs. per square ft.

Bottom curb.—Angle iron, 4 by 4 in.

Vertical legs.—32 legs of 6 in. beam iron. 40 lbs. per yard—trussed.

8 Columns, shafts sheet iron.—Cast iron caps and bases.

8 Lattice girders.—Angle iron chords top and bottom, 5 by 4 by $\frac{1}{2}$ in. angle iron.

Lattice bars.—Flat iron 3 by $\frac{1}{2}$ ins.

—Built by STACEY MFG. CO.,

Cincinnati, Ohio.

TWO-LIFT TELESCOPIC GASHOLDER.

Diameter of upper section, 100 feet.

“ “ lower “ 101 “

Depth on side, 25 feet.

Working capacity, 386,000 cubic feet.

Crown—non-trussed.

Curb.—Two rows of angle iron 5 by 4 ins., one row of flat circular plates 9 by $\frac{3}{8}$ ins.

Crown sheets, center plate 5 ft. diam. $10\frac{40}{100}$ lbs. per square ft.

Curb sheets as above. Intermediate sheets, $4\frac{24}{100}$ lbs. per square ft.

Side sheets, top row—12 lbs. per square ft. Bottom row, $7\frac{24}{100}$ lbs. per square ft.

Intermediate sheets— $3\frac{24}{100}$ lbs. per square ft.

Bottom curb.—Angle iron, 5 by 4 ins.

Cup and grip.—Channel iron 6 by $2\frac{1}{2}$ ins. side plates $7\frac{24}{100}$ lbs. per square ft.

Vertical legs.—32 legs of bulb iron, 6 by $3\frac{1}{2}$ ins. Legs trussed.

Columns.—10 columns, shafts sheet iron, caps and bases cast-iron.

Lattice girders.—Angle iron top and bottom chords, 5 by 4 by $\frac{1}{2}$ ins.

Flat bar iron—3 by $\frac{1}{2}$ ins.

TWO-LIFT TELESCOPIC GASHOLDER.

Diameter of upper section, 122 feet.

“ “ lower “ 124 “

Depth on side, 30 feet.

Working capacity, 682,890 cubic ft.

Crown.—Non-trussed.

Curb.—Two rows of angle iron 6 by 4 ins., and two rows of flat circular plates, 12 by $\frac{1}{2}$ ins. and 9 by $\frac{1}{2}$ ins.

Crown sheets.—Center plate 6 ft. diam. by $\frac{3}{8}$ in. thick.

Intermediate plates.— $5\frac{4}{10}$ lbs. per square ft. Curb plates as above.

Side sheets, top row.— $10\frac{27}{100}$ lbs. per square ft. Bottom row, $7\frac{5}{100}$ lbs. per square ft.

Intermediate sheets.— $3\frac{24}{100}$ lbs. per square ft.

Vertical legs.—48 legs of beam iron, 8 in., trussed.

Cup and Grip.—Channel iron, 8 in. wide. Side plates, $7\frac{24}{100}$ lbs.

Bottom curb.—2 rows of angle irons, 3 by 4 ins.

Columns.—12 columns, shafts sheet iron, caps and bases cast iron.

Girders.—12 lattice girders.

Inlet and outlet pipes—20 ins. diam.

—Builders, STACEY MFG. Co.,

Cincinnati, Ohio.

TWO-LIFT TELESCOPIC GASHOLDER.

Diameter of upper section, 148 feet.

“ “ lower “ 150 “

Depth on side, 30 feet.

Working capacity, 1,000,000 cubic ft.

Crown.—Non-trussed.

Curb.—Two rows of circular flat plates, two rows of angle iron and one ring of channel iron—the whole forming a box girder around upper edge of upper section. The upper flat plates are 15 ins. wide and $\frac{1}{2}$ in. thick, and the lower flat plates 13 ins. wide by $\frac{1}{2}$ in. thick. The angle irons are 6 by 4 by $\frac{1}{2}$ in., and the channel iron 9 by 3 ins.

Crown sheets.—Center plate 6 ft. diam. by $\frac{3}{8}$ in. thick.

Intermediate plates— $10\frac{4}{10}$ lbs. per square ft. Curb plates, $\frac{1}{2}$ in. thick by 1 ft. 3 ins. wide.

Side sheets—Top and bottom rows, $10\frac{7}{10}$ lbs. per square ft. Intermediate sheets, $8\frac{4}{10}$ lbs. per square ft.

Vertical legs.—Upper section to have 28 legs of beam iron, $10\frac{1}{2}$ ins. x $3\frac{1}{2}$ ins.—Legs trussed. Also 28 legs of 8 in. beam iron.

Hydraulic cup and grip.—8 ins. wide, made with $2\frac{1}{2}$ in. angle irons, and bottom plate 8 ins. by $\frac{3}{8}$ ins.—side plates $7\frac{5}{10}$ lbs. per square ft.

Bottom curb.—Two rings of 3 by 4 angle iron.

Columns—14 columns of sheet iron, with cast iron caps and bases.

Girders.—14 Lattice wrought iron girders, 32 ft. long by 3 ft. deep.

THREE-LIFT TELESCOPIC GIRDERS.

Diameter of inner lift—138 feet, 0 inches.

“ “ middle “ —140 “ 6 “

“ “ outer “ —143 “ 0 “

Depth on side—35 ft.

Inner lift.—Crown non-trussed, but with spherical top, with rise of 7 ft.

Curb—Two rings of 6 by 4 in. angle iron. Curb plates, 3 ft. wide by $\frac{1}{2}$ in. thick.

Crown plates.—Center plate 5 ft. diam. No. 10 iron. Outer row, 3 ft. wide by $\frac{1}{2}$ in. thick. Intermediate plates, $5\frac{4}{10}$ lbs. per square ft.

Side plates.—Top row $\frac{3}{8}$ in. thick. Bottom row $\frac{1}{2}$ in., and the intermediate sheets to weigh $4\frac{1}{8}$ lbs. per ft.

Hydraulic cup.—Channel iron, 10 by $2\frac{1}{2}$ ins. Side plate, $\frac{1}{8}$ in. thick.

Vertical legs.—32 legs, flat iron, 8 by $\frac{1}{2}$ in., and two angle irons $2\frac{1}{2}$ by $2\frac{1}{2}$ ins. Legs trussed.

Middle lift.—Top and bottom sheets, $\frac{1}{2}$ in. thick.

Intermediate sheets.— $4\frac{1}{8}$ lbs. per square ft. Grip and cup to this lift made similar to cup on inner lift.

Vertical legs.—To middle lift of channel iron 4 by 1.89 ins.

Outer lift.—Similar to middle lift except at bottom.

Bottom curb.—Two rings of 4 by 4 by $\frac{1}{2}$ in. angle iron.

Inlet and outlet pipes 24 ins. diam.

COLUMNS AND GIRDERS.

16 wrought iron lattice columns, diagonal ties, and 48 girders. Columns 108 ft. 8 ins high, with cast-iron base plate. Column at base 5 ft. 6 ins. by 2 ft. At top 4 ft. by 2 ft.

Girders in three heights.—Girders 3 ft. deep by 12 ins. wide over all. Working capacity, 1,500,000 cubic ft.

—Designed and constructed by R. D. Wood & Co.,
Camden Iron Works, Camden, N. J.

THREE-LIFT TELESCOPIC GASHOLDER.

Diameter of inner lift—156 feet 0 inches.

“ “ middle “—158 “ 0 “

“ “ outer “—160 “ 0 “

Depth on side, 35 ft.—Working capacity, 2,000,000 cubic ft.

Erected in brick tank and building.—Tank 162 ft. diam. by 36 ft. deep. Building 166 ft. diam. by 108 ft. to roof line.

Spherical crown to holder with rise of 8 ft.—Crown non-trussed.—Supported when down by framework of timber.

Vertical legs.—40 legs of angle bar and channel iron.

Top curb, made with angle irons and $\frac{1}{2}$ in. plates, into a continuous girder.

Steel rails are used for guide rails and are secured to building by cast iron brackets ; the guide rails extending from bottom of tank to roof line.

Roof of building constructed of wrought iron, with lantern at apex.

Three galleries extend around the inside of building.

—Designed and constructed by

BARTLETT HAYWARD & Co., Baltimore, Md.

THREE-LIFT TELESCOPIC GASHOLDER.

Working capacity, 1,500,000 cubic feet.

Diameter of inner section—156 feet x 26 feet 4 inches deep.

“ “ middle “ —158 “ x 26 “ 3 “ “

“ “ outer “ —160 “ x 25 “ 4 “ “

Tank 162 feet 6 inches diam. x 28 feet deep.

Spherical crown, supported by an internal frame work of wrought iron. Rise of crown 8 ft.

32 main and 32 secondary rafters, trussed in proportion to strains imposed upon them.

Curb consists of a combination circular girder.

In this holder all the carriages for guide rollers are constructed entirely of wrought iron, and are firmly secured to the vertical stiffeners, and so arranged as to transmit the weight of the entire holder from one to the other, and in this manner relieve the channel bars used in the cups and grips, from all strains acting parallel with their fibre, and converting all strains on the channel bars into compression strains.

The guide frame consists of 16 cylindrical wrought iron columns, with heavy cast iron bases, caps and entablatures. Shafts of columns of wrought iron, 40 ins. diam. at base, and 32 ins. at the cap. Height of column 80 ft. 2 ins.

Two tiers of girders, the upper one on line of entablatures, and the lower one intermediate between upper girder and top of tank.

Guide rails of steel, extending from bottom of tank to top of columns. No counterweights. Two holders as above.

—Designed and constructed by

BARTLETT HAYWARD & Co., Baltimore, Md.

THE HEATING POWER OF COAL GAS.

(CONDENSED FROM A PAPER BY MR. F. W. HARTLEY, BEFORE THE
BRITISH ASSOCIATION OF GAS MANAGERS.

The calorific power of coal gas has often been discussed and statements of practical working results given ; but no record is to be found of the manner in which the heating power is calculated from the composition.

Of late years many very startling assertions have been promulgated respecting the power of gas for heating purposes. Two methods have been practiced for calculating the heating power of coal gas from its composition. One and an erroneous one, based upon the elementary composition of the combustible gases (i. e. upon the respective weights of hydrogen and carbon contained in them) ; and other and correct methods, based upon the actual volume or weight of the several combustible gases which are contained in coal gas.

The method of calculating the heat power of coal gas from the hydrogen and carbon is altogether wrong—because it leaves out of account the amount of heat which has already been expended in effecting the combination of the elements.

From the experiments made on the calorific power of substances, it is known that the calorific power is in general less than the calorific power of its elements in their uncombined state.

The hydrogen marsh gas, carbonic oxide and the illuminating gases are the combustibles. Nitrogen, Oxygen, Carbonic acid and water vapor being under usual conditions, absorbers or abstracters of heat.

The following table compiled by Dr. Letheby shows the calorific power of different gases, including coal gas itself.

POUNDS OF WATER HEATED 1° Fahr.

	Per Cubic Foot.	Per pound of substance
Hydrogen,	329	62,030
Marsh gas,	996	23,512
Olefiant,	1585	21,344
Carbonic oxide,	320	4,325
Common coal gas,	650	21,060
Cannel coal gas,	760	10,140

The calorific power of London gas as analyzed by Dr. Frankland and Mr. Humpidge, and calculated from the above table gives a result of 680 and 660 heat units per cubic foot, and by calculations based on the density of the condensed gases, gives the calorific power of one pound of Dr. Frankland's gas as 21,760 heat units, and 21,780 units for Mr. Humpidge's gas.

The unit of heat is the quantity of heat required to raise one pound of water through 1° Fahr.

These and other experiments represent the highest calorific effects obtained from a 16 candle power coal gas.

In the ordinary use of coal gas for heating water its calorific power is much below that shown by calculation; very much of the heat passes off to waste with the products of combustion, and the nitrogen associated therewith. An excess of air also carries off much of the heat. In ordinary use the amount of heat lost is fully 200 units.

From actual experiments made with Bunsen burners, by the writer (F. W. Hartley) the indicated calorific power, after correction for barometric pressure and temperature, ranged from 365 to 392, the average results being 282 units per cubic foot.

Experiments made under similar conditions, and using each burner in such manner, and with such rate of consumption, as was found to give the highest effect, a cluster of small fish-tail burners give results equal to 98 per cent, of the standard, an 8 tube Bunsen burner 92 per cent., Wallace's solid flame 97 per cent., a burner called the Egyptian 91 per cent., another known as the Depore 83 per cent., two others gave 93 and 87 per cent. respectively.

Taking the average of the results realized with the best, and with all the many other gas-stove boilers tested we have 360 units indicated as the power of the gas per cubic foot, in raising water to 210° or 211° Fahr.

If the real power of the gas employed, was on the average 680 units, 320 units or 47 per cent. of its heat was lost.

The average result of experiments made by Mr. Lewis Thompson with the gases of several companies gives 374 units per cubic foot.

The higher the temperature to which water is raised by the aid of gas or other fuel, the smaller will be the amount of heat utilized.

THE HEATING POWER OF COAL GAS.

(CONDENSED FROM A PAPER BY DR. JAMES ADAMS OF GLASGOW.)

The heating power of coal gas must always remain an uncertain quantity, for coal gas is not a pure elementary substance of homogenous composition, and of fixed properties, but on the contrary, is a very variable mechanical mixture of numerous gases and vapors, the proportions and numbers of which differ according to the nature of the coal, and of the special manufacturing processes employed. (Therefore to speak of the heat units in a coal gas, without stating the quality of the gas, is to omit a most important factor.—Ed)

“Box on Heat” says that “the total heat of coal gas is 696 units per cubic foot. Dr. Letheby states that the heat of *common* coal gas is 650 units, and that of *cannel* coal gas 760 units per cubic foot.

Mr. Harcourt’s estimate of a gas analyzed by him is 22684 units per lb. or 756 units per cubic foot. Dr. Wallace, after premising that “as regards the heating power of coal gas we have no definite information, gives the result of some experiments on three qualities of coal gas in which he estimates that “he realized about 55 per cent. of the theoretical heating power.” From his data the three samples contained theoretically 631,827, and 949 units per cubic foot.

Although no elaborate investigation has been made of the heating power of coal gas in its entirety, such observations have been made on the elementary constituents, particularly on Hydrogen and Carbon which in their various combinations, essentially compose coal gas, and also upon the compounds in which these elements are united.

There is no standard of heating force, no absolute measure of heat, and the calorific power of a fuel can only be estimated relatively—by comparing the effects produced by equal weights of different kinds of fuel.

As illustrating the different values of the heating power attributed to hydrogen, it will be instructive to cite a few examples.

According to Dulong 1 lb. of hydrogen is capable of producing heat that will raise the temperature of 62,585 lbs. of water through 1° Fahr.

In two experiments made of the heating power of a certain coal gas, in the first of which the above value of hydrogen was taken, and in the second the value of hydrogen given by Favre and Silberman, viz:—62,032 units per lb. The first estimate was 21,511 units per lb. of the coal gas, or 794 units per cubic ft., the second estimate was 20,967 units per lb. or 774 units per cubic ft. Another estimate of the same gas was 20,736 units per lb., or 765 units per cubic ft.

Prof. Andrews, a more recent investigator and a high authority, gives his estimate for hydrogen at 60,986 units

Older authorities than either of the above quoted, viz:—Despretz, Laplace and Clement have respectively appraised hydrogen at 42,552, 42,120 and 39,807 units.

The latest and most reliable estimate is that of Thomsen of Copenhagen, whose value of hydrogen is 61,524 units. Carbon by almost unanimous consent, is taken at 14,544 (Dulong values it at 12906 units, and "Box on Heat" uses this figure in his work.)

Another fallacy and serious cause for discrepancy arises when it is assumed that the heat of combustion of a composition is the same as that of its elements. The fact is usually the reverse.

Thus marsh gas CH_4 , which forms more than one-third of the bulk of coal gas, is composed of three parts by weight of carbon, and one part by weight of hydrogen. In one pound of marsh gas the heat of combustion of its elements *when they are burned separately*, is for carbon 10,914 units, and for hydrogen 15,881 units, making a total of 26,295 units as the combined heats which 1 lb. of marsh gas ought to yield. But by actual experiment the heat evolved is only 23,616 units; hence marsh gas in burning evolves 2,672 units per lb. less than its elements.

In explanation of these phenomena it is supposed that the combination of carbon and hydrogen to form marsh gas is accompanied by evolution of heat, and that their separation from the state of combination in the act of combustion is also attended by the disappearance of an equal quantity of heat. These suppositions have been proved to be facts by actual experiment.

Some compounds evolve practically in their combustion nearly as much heat as is supposed to be possessed in their elements; *in certain instances even more*, as in olefiant, ethylene and benzole.

Box on heat page 55.—The presence of oxygen in a combustible containing hydrogen has the effect of reducing its heating power; for when a combustible contains 8 lbs. of oxygen to 1 lb. of hydrogen, being the ratio in which they combine to form water, they do so combine, but give out no useful heat; whereas if hydrogen alone is present it yields the full amount of heat due to it. When oxygen is present, but in too small a proportion to combine with the whole of the hydrogen, it combines with one-eighth of its weight and leaves the rest as an *excess of hydrogen* which yields its due proportion as before.

The following table gives the analysis as published of 12 English coal gases, and in one instance a mean of 6 analyses is comprised in a single estimate.

Constituents of Coal Gas.	1	2	3	4	5	6	7	8	9	10	11	12
	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.
Hydrogen.....	45.58	46.0	27.7	46.77	41.15	51.24	51.80	47.83	50.28	47.60	41.72	25.82
Marsh gas.....	34.90	39.5	50.0	38.18	40.66	35.28	35.26	36.94	36.95	41.53	41.88	51.20
Olefiant	4.08	3.8	13.0	5.03	3.67	3.56	3.53	7.02	6.34	6.97	19.66	22.98
Quartene.....	2.38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbonic oxide.....	6.64	7.5	6.8	5.69	8.02	7.40	8.95	5.27	4.37	7.82	4.98	7.85
Sulphuretted hydrogen.	0.29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbonic acid.....	3.67	0.6	0.1	1.81	0.29	0.28	.....	.....	.....	.....	.....	0.13
Nitrogen.....	2.46	0.5	0.4	2.39	5.01	1.80	0.38	5.29	.....	.....	2.71	1.51
Oxygen.....	.....	.....	.....	0.10	1.20	0.44	0.08	0.56	.....	.....	.....	0.43
Aqueous vapor .....	.....	2.0	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
Heating power from combustion of constituents, in state of combination.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Heat units per lb.....	18,860	21,290	21,181	20,702	18,858	21,542	22,126	20,644	23,679	22,739	21,987	20,778
" per cubic ft.....	696	663	863	666	658	632	637	690	655	747	932	1,041
Heating power from combustion of elementary constituents separately burned.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Heat units per lb.....	20,736	22,777	22,848	22,586	20,763	23,365	24,112	22,415	26,492	24,693	24,237	22,238
" per cubic ft.....	765	709	931	727	729	686	693	748	732	811	1,019	1,114
Candle power.....	21	12	20	.....	16	12	12	16	12	13	20	34
Specific gravity.....	.457	.387	.506	.399	.432	.363	.356	.411	.342	.406	.526	.620
Cubic ft. per lb.....	27.09	32.10	24.53	31.06	28.64	34.06	34.79	29.95	36.15	30.44	23.59	19.96
Heat units less per lb. in combination than is evolved by elements separately burned.....	1876	1487	1607	1884	1905	1823	1986	1771	2813	1954	2250	1460

One important point made plain by this table is that the heating power of coal gas theoretically estimated is not a *fixed quantity* neither can it be estimated by the cubic foot.

The table shows that from 632 to 1041 units may be contained in a cubic foot of gas, or from 18,858 to 27,679 units in one pound of gas, a variation too great to admit of a safe average.

The last line of the table shows that an average exceeding 8 per cent. of heat units becomes absorbed or latent in the elementary constituents when they are in a state of combination. In other words there is from 8 to 9 per cent. less of heat units evolved by the combustion of coal gas in its entirety, than is given out by its elementary constituents when separately burned.

The heating power is seen to increase with the specific gravity, and it may be safely taken that the heavier the gas the greater is the heating power bulk for bulk—that is provided the gas contains little or no carbonic acid, which does not contribute to but detracts from the heating as well as the lighting value, and also that there is no excess of carbonic oxide, which has little heating force in comparison with the other carbon compounds. The greater the amount of carbon, except in the above objectionable forms, the greater the heating power—but very much depends upon the form in which this element is present. It is obvious that the heating power is more effective as the material of combustion is more concentrated.

The heat-evolving constituents of gas fuel, as indeed of all fuels consists, with insignificant exceptions, of hydrogen and carbon, the former possessing the highest amount of heating power in proportion to weight, but much the lowest in proportion to bulk, and it is mainly through the amount of condensation which these elements undergo in their combinations—that the heating value of a cubic foot of one coal gas so far exceeds another.

The same holds good with respect to the illuminating properties. For many years the highest place has been accorded to olefiant gas, and it was long considered the true illuminating principle of coal gas—but it has now come to be taught that the true

illuminating principle of coal gas should properly be attributed to benzine or benzole vapor, and it has been shown that besides its high illuminating property, benzine has a calorific force far exceeding olefiant gas.

Berthelot of Paris has shown that the proportion of olefiant in some gases of good illuminating quality is exceedingly small—in that of Paris only 1–30,000th part of a percentage, while benzine was present in the proportion of 8 to 3½ volumes in 100.

Prof. Ditmar has shown that a mixture of hydrogen and olefiant gas, in so large a proportion as equal parts by volume burns with an almost non-luminous flame; while hydrogen containing so little as only 3 volumes of benzine in 100 burns with a very bright flame. Frankland and Thorpe have more recently determined the illuminating power of benzine in combination with hydrogen with carbonic oxide, and with marsh gas, (to the exclusion of olefiant gas) in various proportions, and found that they gave the light of from 70 to 94 candles, thus confirming the observations of Berthelot and Ditmar.

The natural deductions from these investigations are that the illuminating power of coal gas is due mainly to the presence of benzine, and that intensity of a flame is not owing to the numerical relation of the carbon to the hydrogen, but to *the condensation of their elements in the unit or molecule of fuel*. Another authority says: "It is highly probable that the illuminating value of coal gas depends much more on the presence of benzole vapor than on the proportion of the heavy gaseous hydrocarbons, and the estimation of benzole in the gas is a point which has hitherto been comparatively neglected.

In the following table the weight in grains of one cubic foot of the chief constituents of coal gas have been calculated, and their heating power shown in parallel columns. From the weight so calculated and with the aid of the other portions of the table, the heat which any coal gas is capable of producing during perfect combustion may be ascertained.

NAMES OF CONSTITUENTS OF COAL GAS.	Chemical Symbol.	Atmospheric Weight	Weight of 1 Cubic Ft. in Grains at 32° Fahr.	Lbs. of Water raised 1° Fahr. by 1 lb. of Gas.	Weight in Grains of 1 Cubic Ft. of Gas raised 1° Fahr. the following quantities of			
					Lbs. of Water at 32° Fahr.	Lbs. of Air.	Cub. Ft. of Air at 32° Fahr.	Cub. Ft. of Air at 62° Fahr.
Hydrogen.....	H	1	39 048	61,524	343	1,442	17,862	18,948
Marsh Gas—Methane.....	CH ₄	16	312,384	23,616	1054	4,428	54,850	58,185
Acetylene—Ethine.....	C ₂ H ₂	26	507,624	21,500	1559	6,551	81,140	86,079
Olefiant Gas—Ethylene.....	C ₂ H ₄	28	546,672	21,523	1681	7,062	87,491	92,800
Butylene-quartene.....	C ₄ H ₆	56	1093,344	21,255	3320	13,949	172,786	183,289
Benzene—Benzole Vapor..	C ₆ H ₆	78	1522,872	21,500	4677	19,621	243,026	258,239
Sulphuretted Hydrogen...	H ₂ S	34	663,816	7,143	667	2,846	35,250	37,398
Carbonic Oxide.....	CO	28	546,672	4,295	355	1,409	17,452	18,518
Carbonic Acid.....	CO ₂	44	859,056	.....	.....	.....	.....	.....
Oxygen.....	O	16	624,768	.....	.....	.....	.....	.....
Nitrogen.....	N	14	546,672	.....	.....	.....	.....	.....
Aqueous Vapor.....	H ₂ O	18	351,432	.....	.....	.....	.....	.....

The following table is compiled from statistics gathered from various localities. It gives the average of 714 tests for candle power, and 94 analyses, determining the specific gravity—showing the connections between specific gravity, candle power and heating power of illuminating gas.

AVERAGES.

Candle Pow'r varying from	Specific Gr. Air=1000.	Candle Pow'r	Cubic Ft. in 1 Lb. of Gas.	Heat Units per Cubic Ft.*
10 to 12	.405	11.0	32.4	679
13 " 16	.463	14.5	28.4	775
17 " 20	.530	18.5	24.8	887
21 " 24	.548	22.5	23.9	920
25 " 28	.575	25.3	22.8	965
29 " 32	.606	30.5	21.7	1014
33 " 36	.640	34.5	20.5	1073
37 " 40	.704	38.7	18.7	1176

*Calculated from an average 23,000 heat units per pound of gas.

From the above table a practically useful approximation may be reached of the value of any gas of which the specific gravity is known.

The tendency of writers on the subject of the heating power of coal gas, has been of late, to take lower values than were at one time recognized. This is probably due to improved methods and apparatus now used in making the tests.

The standard calorific power of the gas supplied under contract by the different French companies is equal to 584.2 heat units.

From the above extracts, and remarks of different experts, upon the heating power of coal gas, there seems to be only one or two points of agreement. 1st.—That we know very little on the subject. 2d.—That the instruments and methods of testing are too imperfect for correct work. 3d.—That the heavier the gas the better it is for heating purposes, also the richer the gas the better it is for fuel.

GAS ENGINES.

The name of Gas Engine, is applied to those Engines in which the motive power is obtained by the expansion of a mixture of air and gas, the expansion being caused by the explosion or rapid combustion of the compound.

The principal parts of a gas engine are similar to those of the steam engine, viz., the cylinder which receives the explosive gaseous compound, the piston and crank which transmit the motion to the shaft, the fly wheel and governor, &c., &c. The gases expanded by combustion act upon the piston, as does steam in the steam engine.

Upon the mixture of the air and gas, in proper proportions, and the regulation of the explosions, depend the efficiency of the gas engine, and this governing principle is the point of greatest difference in the engines of various makers. In the explosion of the mixture the products are expanded to an enormous extent, at the moment of combustion.

It will be readily seen that there is a great economy in the use of gas engines, from the fact that there is no fire to build, no water to heat, nothing to do in fact, but to strike a match, and start the engine. *Furthermore the gas engine consumes fuel only while it is doing its work.*

Gas Engines also give no trouble arising from coal dust and ashes, no risk of explosion, and no engineer nor fireman is required.

The invention of gas motors dates back to the early days of gas lighting, but no great progress was made with them until the invention of Lenoir and Hugon in 1858 and 1859 which were sufficiently perfect for industrial purposes. These engines are now obsolete, but they were the first in the field and deserve mention. The gas was exploded at each end of the cylinder, acting directly on the piston. The gas was ignited in one case by a light injected into the cylinder, and in the other by an electric spark. In these early engines the consumption of gas was 70 cubic feet per hour per HP.

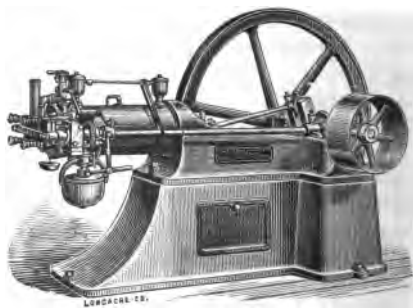
Next to these Otto and Langen's vertical engines were introduced; these were not made larger than 3 HP, but they were very economical in their working, only using 20 cubic feet of gas per hour per HP. Not satisfied with the results obtained with this engine, it was made by the inventor and manufacturers the subject of numerous experiments, which have resulted in the pro-

duction of the Otto Silent Engine. At the same time other inventors were at work, and the result has been that numbers of engines have been invented, some good and some only passable. Numerous small engines have been produced which are mainly used for pumping, for which purpose they serve very well.

The three prominent gas engines, now in general use, are the Otto, the Korting and the Clerk. We will give a brief description of each, giving also the claims made for each by the manufacturers.

THE OTTO GAS ENGINE.

The Otto Gas Engine consists mainly of a jacketed cylinder with piston, slide valve and customary crank shaft and fly-wheel. The new "Crossley" patented governor, with cut-off mechanism performs the double function of regulating the speed and measuring the admission of gas according to the demand made each moment upon the engine. This is a decided improvement on all governors heretofore used on gas engines. It is very sensitive, almost frictionless, and is an important element in the saving of gas in the Otto engine.



The source of power in these engines is due to the combustion of a peculiar mixture of gas and air ignited in the cylinder. A small part only of the charge is combustible, which on ignition serves to expand the remainder thus avoiding shock and saving gas.

No skilled attendance is necessary, as these engines can be run entirely by unskilled labor.

The Otto engine is now made vertical as well as horizontal. The vertical engines occupy small space, and are useful as small

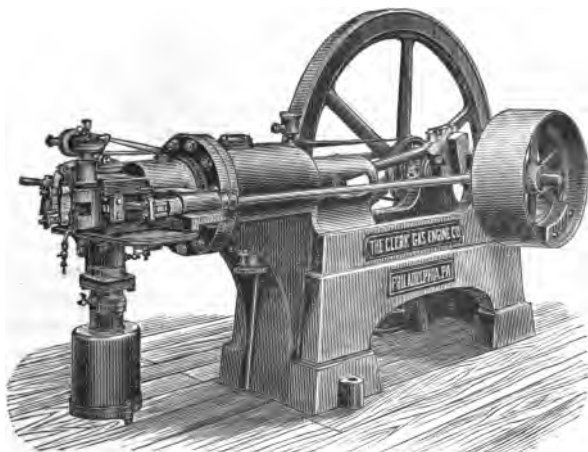
motors, for printing offices, tea and coffee stores, ice cream freezers, ventilating fans and blowers, organ blowing, pumping water, sewing machines, etc., etc.

The Otto horizontal engines are now made in large sizes, up to one hundred horse power.

A great and growing use for these engines, is in the running of dynamos for generating electricity, a work for which they are well suited.

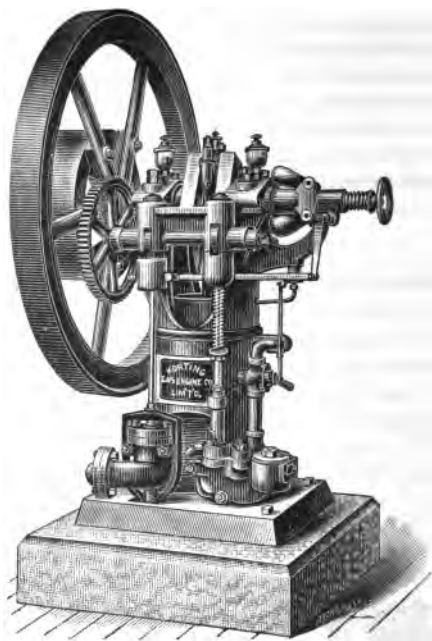
THE CLERK GAS ENGINE.

This engine, made by the Clerk Gas Engine Co., is a horizontal engine, the general features of which are shown in the illustration. Its makers claim for it a low pressure and a small consumption of gas, a limited floor space, a loss of only $\frac{5}{8}$ of 1 per cent. by the explosions, and a low price, combined with superior workmanship. They also guarantee the engine for one year.



THE CLERK GAS ENGINE.

The Korting is a vertical engine, and can be used with any kind of gas, either manufactured or natural, by a patent self-acting mixing valve, which is readily adjusted for any kind of gas.



THE KORTING GAS ENGINE;

The patent mixing valve makes the proportion of gas and air remain the same, but the quantity admitted is altered, so as to give an explosion of the requisite strength to overcome the resistance of the work. The leading features of the Korting universal adjustable governor, are two independent movements, derived from the main shaft. The *first* for uniformly opening the exhaust valve, and the *second* being influenced by the governor, varies the time of closing the said valve, depending on the speed of the engine.

It is easy to understand that the power of the engine may be influenced by the length of time during which the exhaust valve is kept open during the return stroke of the piston—the earlier the valve is closed, the larger the quantity of the products of combustion, retained in the cylinder, and the smaller the amount of fresh gas required to again fill the cylinder to secure uniform compression, and a perfect combustible mixture for next working

stroke of engine. Simply stated, the Korting differs from other gas engines in regulating the speed by the working of the exhaust valve, which in turn regulates the admission of the combustible mixture, maintains uniform compression and complete combustion under all contingencies.

The Korting engine being vertical, and compactly built, occupies but a limited space. A ten horse power engine only requires 20 square feet of floor space, and weighs but two thousand pounds.

The economy of gas engines is one of their greatest merits. They need no skilled and licensed engineer to run them: they require no attention; they are perfectly safe as regards explosions and fire; no extra insurance is required by reason of their use; they require no boiler, no brick work, no tall chimney, and there are no ashes to remove. They work silently, and do their work as effectively as a steam engine, and the consumption of fuel goes on, *only while the engine is at work*. They can be started by the striking of a match, and stopped by turning off the gas.

They are especially useful in places where the work is required for short and intermitting periods, as for pumping water for house purposes, there is no fire to keep up when not wanted, and the engine can be started instantly, and stopped when the work is done. In view of all these advantages, it is not strange that the manufacture of gas engines is one of the most promising industries of the day. New uses for them will be found, and in fact its use as a motor for street and elevated railways is now out of experimental stage, and will be tested on a suburban street railway in a few days. This is the invention of Connelly & Co., and consists of a continuous running engine, supplied with gas from tanks, carried on top of the car.

This style of motor will without doubt be more economical and effective, than cable traction or electricity. Why this system of propulsion for street cars, has not been adopted before this, is a wonder, as it seems to be the only system that fulfils perfectly the requirements of city traffic. For use on the elevated railroads it will quickly consign to oblivion the use of steam, with its attendant nuisances of water, coal, ashes, and smoke, and at the same time greatly reduce the cost of running.

Gas engines are peculiarly well adapted to the requirements of gas works, the fuel is ready to hand, light power, with steady, continuous running is wanted, and yet the number of gas engines

so used is small. How can Gas Co's. expect to extend their use if they do not set the example themselves.

The price of gas is being reduced every day, and this fact alone will help greatly to increase the use of Gas for Light, Heat and Power. The great desire of all engineers has always been to increase the day consumption, so that the plant, or a great portion of it, shall not be idle half of the time. The process of Heating and Cooking by gas, and the use of gas as a motive power, are yet in their infancy, and there seems no good reason to doubt, that with proper exertion, (owing to the spur of competition, and the low margin of profit at which gas must in the future be sold,) that at not very distant day, the amount of gas used in the day time will equal that used at night.

As to the means by which this desired state of things may be achieved, a few may be suggested, such as hiring out of stoves for heating and cooking, canvassing, advertising, by circular to consumers, and keeping on exhibition in a room attached to the general office, every appliance and motor, where they can be seen, and their working explained by a competent clerk. This is done at present by some large companies, and with good results. Finally the Gas Co's. must abandon the idea that their principal business is gas lighting, and the other things only a side issue.

PROPERTIES OF FUEL.

KIND OF FUEL.	Lbs of water evaporated per lb. of fuel.	Per cent. of carbon	Cubic ft. of air req'd for one lb. of fuel.	Weight per cubic foot.	Cubic feet per ton.
Bituminous Coal.....	7 to 9	80	265	50	44
Anthracite Coal.....	8 " 10	92	282	54	48
Coke, Virginia.....	8 " 9	80	260	48	48
Coke, Cumberland.....	8 " 10	80	250	82	70
Charcoal.....	5 " 6	96	265	24	104
Dry Wood.....	4 " 5	44	147	30	100
Wood with 20 per cent water.	4 " 0	34	115	25	100
Turf dry.....	6	51	165	28	80
Turf, 20 per cent. of water..	5	40	132	30	75
Oil, wax, tallow.....	14	77	200	59	37
Alcohol, 95 per cent.....	9.56	58	154	52	42

Chemically one pound of Carbon, burnt to Carbonic Acid requires the Oxygen of 153 cubic feet of Air.

NYSTROM.

“HEAT DEVELOPED BY DIFFERENT LIGHT SOURCES.”

The amount of heat units developed per 100 candle power per hour.

W. PENKERT.

Incandescent Lamps of

Sieman's and Halske.....	427
Edison.....	355
Swan.....	430
Bernstein.....	153

Illuminating Gas with

Siemen's Burner.....	1500
Argand Burner.....	4860
Double Light Burner.....	12150

Mineral Oils with

Argand Burners.....	3360
Flat Wick Burners.....	7200

Solar Oil with

Schuster & Bear's Lamp.....	3360
Small Flat Wick Burner.....	7200

Rape Seed Oil with

Carcel Lamp.....	4200
Student Lamp.....	6800
Paraffine Candles.....	9200
Wax or Sperm.....	7960
Stearine.....	8940
Tallow.....	9700

COMBUSTION.

Combustion is the rapid chemical combination of substances with oxygen O. Carbon C, and Hydrogen H, are the substances most generally employed for generating heat. Carbon is fully consumed when combined with oxygen, to form carbonic acid gas CO_2 , and partially consumed when in the form of carbonic oxide CO or smoke.

Our fuel and lights, such as wood, coal, oil, etc., consists mainly of carbon and hydrogen, and are therefore called hydrocarbons. In burning they unite with the oxygen of the air, forming H_2O water, and CO_2 carbonic acid gas.

These both pass off, the one as a vapor and the other as a gas. Ashes compose the mineral matter contained in the fuel. When the fuel is first put in the furnace the hydrogen is liberated with some carbon in the form of olefiant C_2H_4 or marsh gas CH_4 , this burns with a flame. After the hydrogen has passed off the carbon is left, which burns as coal merely.

In the burning of fuel nothing is destroyed; the water, carbonic acid, and the ashes weigh as much as the fuel, and the oxygen that combined with it. No matter how rapidly the fuel burns, the elements unite in exact atomic weights.

Sometimes chemical changes take place in combustible substances, whereby heat enough is generated to cause ignition. Lime CaO occasionally absorbs H_2O so as to set fire to wood in contact with it. Fresh burned charcoal has the power of absorbing gases in its pores so rapidly as to become ignited. Coal exposed to the weather takes fire from the sulphurous compounds contained in it in the form of iron pyrites, etc., which are decomposed by the moisture of the air. Oily cotton waste when thrown in heaps will often absorb oxygen enough to ignite. The same will happen to a mixture of oil and sawdust.

In the chemical combinations called combustions, the carbon combines with the oxygen of the air forming carbonic acid, and the hydrogen similarly combining, forming water, thus $\text{C} + \text{O}_2 = \text{CO}_2$, and $\text{H}_2 + \text{O} = \text{H}_2\text{O}$. In the following table is given the chemical composition of combustibles according to Pecklet, etc.

(From Box on Heat page 55.)

ELEMENTS.	Carbon.	Hydrogen.	Oxygen.	Nitrogen and Sulphur.	Water.	Ashes.	Total.
Coal, mean of 97 kinds.	.804	.0519	.0787	.0246	.....	.0408	1,000
Coke.....	.850	.....	.....	.....	.....	.150	1,000
Wood, perfectly dry...	.510	.053	.417	.....	.....	.020	1,000
“ ordinary state...	.408	.042	.334	...	.200	.016	1,000
“ charcoal.....	.930	.....	.....	.....	.....	.070	1,000
Peat, perfectly dry....	.580	.060	.310	.....	.....	.050	1,000
“ ordinary state....	.464	.048	.248	.....	.200	.040	1,000
Oil of Turpentine.....	.884	.116	.....	.....	.....	.....	1,000
Alcohol.....	.5198	.1370	.3432	.....	.....	.....	1,000
Olive Oil.....	.7721	.1336	.0943	.....	.....	.....	1,000
Sperm Oil.....	.789	.1097	.1013	.....	.....	.....	1,000
Tallow.....	.790	.117	.093	.....	.....	.....	1,000
Paraffine Oil.....	.8522	.1478	.....	.....	.....	.....	1,000
Resin.....	.7927	.1015	.1058	.....	.....	.....	1,000
Sulphuric Ether... ..	.6531	.1333	.2136	.....	.....	.....	1,000

The presence of oxygen in a combustible containing hydrogen has the effect of reducing its heating power; for when a combustible contains 8 lbs. of oxygen to 1 lb. of hydrogen, being the ratio in which they combine to form water—they do combine but give out no useful heat—whereas, if hydrogen alone is present, it yields the full amount of heat due to it. When oxygen is present, but in too small a proportion to combine with the whole of the hydrogen, it combines with one-eighth of its weight, and leaves the rest as an *excess of hydrogen* which yields its due proportion of heat as before.

The heat units taken for carbon and hydrogen are those of Dulong; for carbon 12,906 units per lb., and for hydrogen 62,535 units per lb.

The heat units of compound substances can be calculated from the table as follows:

Oil of turpentine consists of .884 of carbon and .116 hydrogen and 1 lb. of it will yield—

Carbon..... $.884 \times 12,906 = 11,409$ units of heat.

Hydrogen ... $.116 \times 62,535 = 7,254$ “ “ “

Total..... $18,663$ “ “

Alcohol will serve to illustrate the effects of the presence of oxygen in a combustible. It is composed of .5198 carbon, and .3482 oxygen. As oxygen requires one-eighth part of its weight

to form water, it will require in alcohol $\frac{.3482}{8} = .0429$ hydrogen.

As there is contained in alcohol already .187 of hydrogen, there remains therefore $.187 - .0429 = .0941$ hydrogen in excess to develop its heat, and we have—

Carbon.....	.5198	$\times 12,906$	$= 6,708$	units.
Hydrogen in excess..	.0941	$\times 62,585$	$= 5,885$	"
			<u>12,593</u>	"

Paraffine oil or petroleum, composed of carbon .8522 and hydrogen .1478 will give—

Carbon.....	.8522	$\times 12,906$	$= 10,998$	units.
Hydrogen.....	.1478	$\times 62,585$	$= 9,242$	"
			<u>20,240</u>	"

Coal as per table gives—

Carbon.....	.804	$\times 12,906$	$= 10,376$	units.
Hydrogen, (.0519 — .0787) =	.04206	$\times 62,585$	$= 2,630$	"
			<u>8</u>	
			1,8006	"

Coke containing .85 carbon and no hydrogen or oxygen will yield $.85 \times 12,906 = 10,970$ units of heat.

The heating power of combustibles as per the preceding calculations is the maximum effect they are capable of producing.

The effect of water in a combustible is two fold—wood in its ordinary state containing 20 per cent. water, reduces the really combustible matter to 80 per cent. of the amount contained in the same weight of wood perfectly dry, and the calorific power is reduced in the same proportion. The second effect is, that part of the heat in the residue is consumed uselessly in evaporating the water.

The following table gives the calorific power of combustibles, by experiment and theory:

It will be seen from the table that the experiments differ widely in their results.

THE CALORIFIC POWER OF COMBUSTIBLES.

BY EXPERIMENT AND THEORY.

	Units of Heat per lb. of Fuel by Exprim't	AUTHORITIES.	Units of Heat per lb. of Fuel by Theory.
Hydrogen burning to water	62585	Dulong.....	
" " " "	62082	Favre and Silberman.	
" " " "	42120	Laplace ..	
" " " "	39807	Clement.....	
" " " "	42552	Despretz	
Carbon burning to car- bonic acid.....	12906	Dulong.....	
Carbon from wood burn- ing to carbonic acid.	14544	Favre and Silberman.	
Carbon burning to car- bonic acid	14040	Despretz.....	
Carbon burning to car- bonic oxide.....	2495	Dulong.....	
Carbon burning to car- bonic oxide.....	4453	Favre and Silberman.	
Carbonic oxide burning to carbonic acid....	4478	Dulong.....	
Carbonic oxide burning to carbonic acid....	4325	Favre and Silberman.	
1 lb. carbon in the form of carbonic oxide burn. to carb'nic acid	10411	Dulong... ..	
Wood perfectly dry by artificial heat.....	6480	Rumford.....	6582
Wood, ordinary state of dryness.....	5040	"	5265
Colza oil... ..	16753	"	
Alcohol.....	12339	Dulong.....	12598
"	11151	Rumford	
Sulphuric ether.....	16974	Dulong.....	15095
Tallow	15550	Rumford.....	16792
Naphtha, density .827....	13208	"	
Sulphur.....	4682	Dulong.....	

Box on Heat.

TABLE SHOWING THE COMPARATIVE VALUE FOR CERTAIN INDUSTRIAL PURPOSES
(GAS ENGINES, ETC.) OF VARIOUS HEATING GASES.

	1 Generator gas from coke or anthracite.	2 Generator gas from anthracite, coke, &c.	3 Generator gas from fine coal and breeze.	4 Generator gas from breeze.	5 Ordinary water gas from coke, anthracite &c	6 Commercial hydrogen gas.	7 Ordinary illuminating gas from coal.
Carbonic oxide.....	21.76	27.32	21.41	22.76	46.50	4.65	6.25
Hydrogen.....	10.88	13.34	2.39	11.53	43.25	86.15	20.00
Olefiant gas....	1.10	1.25	4.49	5.13	1.45	1.30	58.00
Marsh gas.....	1.88	1.55	2.09	2.10	1.20	1.45	9.50
Tar vapors....	Traces	Traces.	0.80	0.90	Traces	Traces.	1.25
Oxygen.....	35.07	48.46	31.18	42.42	92.50	93.55	95.00
Nitrogen.....	61.36	47.84	64.16	53.66	4.00	7.20	3.50
Carbonic acid.....	3.57	3.60	3.78	3.85	4.00	0.65	1.50
Sulphur dioxide.....	.....	0.04	0.03	0.03	0.04	0.03	Traces
Sulphuretted hydrogen.....	.....	0.06	0.04	0.04	0.06	0.07	..
Total.....	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Caloric power of 1 cubic meter.....	Calories. 1210	Calories. 1520	Calories. 1475	Calories. 1858	Calories. 2710	Calories. 2686	Calories. 5650
Net cost per cubic meter.....	Centimes. 0.80	Centimes. 1.00	Centimes. 0.75	Centimes. 0.90	Centimes. 2.50	Centimes. 9.70	Centimes. 5.00
Price per 1000 calories.....	0.66	0.65	0.51	0.48	0.93	3.61	0.89
Comparative price.....	1.88	1.35	1.27	1.00 *	1.91	7.52	1.85

a, Crude gas. b, Washed gas. c, Gas washed and purified with lime. d, Gas washed and purified with Oxide of Iron. *Units of comparison.

TESTS OF AMERICAN REGENERATIVE GAS LAMPS.

FROM THE REPORT OF COMMITTEE ON GAS UTILIZING APPARATUS
"FRANKLIN INSTITUTE OF PHILADELPHIA, 1885."

WASSERMAN'S REGENERATIVE GAS LAMPS.

An Argand burner with circular flame, and admitted as in the common Argand. One current passes up centrally supplying oxygen to the interior of the flame, and another passes up upon the outside and supplies oxygen to the outer surface. In the center of the burner springing upwards from the base is a metal pipe which expands toward the top into a hollow cone, which is surrounded by a shell of porcelain. The heat of the flame is such as to raise the surface of cone to a high temperature, and the ascending current of air is heated as it rises, and the combustion takes place at a higher temperature, and produces a higher degree of incandescence. The tests gave the following results.

Candle power of city gas.....	16.20		
Candles per foot of gas.....	3.20		
		Test No. 1.	Test No. 2.
Gas burned per hour, cubic feet.....	10.50	9.00	
Candle power.....	38.06	38.95	
Candles per foot of gas.....	3.62	4.32	

SIEMEN'S REGENERATIVE GAS LAMP.

The central principle on which the efficiency of this lamp depends is the heating of the air and gas intensely before they reach the zone of combustion, by the waste gases which are passing away from the flame. This heating or regenerative action is also cumulative, and increases with the rising temperature of the flame. The waste gases are carried away by a flue, after they have done their work in the lamp—leaving the air of the room uncontaminated.

Tests were made on a bar photometer, with a length of 280 ins. between the lamp—and standard—which was a Sugg Argand burner, rated to pass 5 feet of gas per hour.

HORIZONTAL TESTS OF SIEMEN'S LAMP.

Candle power of standard and city gas.....	17.71		
Candles per foot of gas.....	3.54		
		Test No. 1	Test No. 2. Test No. 3.
Gas burned per hour cubic feet... 51.18	51.18	48.00	
Candle power.... 364.65	403.11	396.52	
Candles per foot of gas 7.12	9.04	8.26	

LUNGREN INVERTED REGENERATIVE GAS LAMP.

This lamp owes its efficiency to the heating of the air and gas which enter the flame, by the waste heat.

The flame and illumination is all below the structure of the lamp itself—there are no shadows; and the light thrown down from the lamp is unobstructed.

The quality of the light for brilliancy, steadiness, and color is unsurpassed; and the lamp itself is simple in construction and of a pleasing design.

HORIZONTAL TESTS OF LUNGREN INVERTED LAMP.

Candle power of city gas.....	17	69	
Candles per foot of gas.....	3.54		
	Test No. 1.	Test No. 2.	Test No. 3.
Gas burned per hour, cubic feet..	16.44	17.85	17.25
Candle power.....	124.71	155.84	157.62
Candles per foot of gas.....	7.58	8.7	9.12

45° ANGLE TEST OF THE SAME.

Candle power of city gas.....	18.60		
Candles per foot of gas.....	3.72		
	Test No. 1.	Test No. 2.	Test No. 3.
Gas burned per hour cubic feet..	16.20	16.65	17.20
Candle power.....	197.16	231.78	230.64
Candles per foot of gas... ..	12.17	13.09	13.04

VERTICAL TESTS OF THE SAME.

Candle power of city gas.....	18.60
Candles per foot of gas.....	3.72
Gas burned per hour cubic feet.....	16.00
Candle power.....	223.86
Candles per foot of gas	13.99

ALBO CARBON LAMP.

Candle power of city gas.....	17.25	
Candles per foot of gas.....	3.45	
	Test No. 1.	Test No. 2.
Gas burned per hour, cubic feet.....	4.80	4.95
Candle power.....	29.70	41.10
Candles per foot of Gas	6.18	8.33
Naphthalene consumed per 1000 feet of gas.....		2.88 lbs.
Cost of do. do. at 12 cts. per lb.....		34.5 cts.
Cost of city gas \$1.60 Do. of carburetted gas.....		\$1.94½

IMPROVED BURNERS.

Great attention has of late been given to improvements in burners, and lamps. One of the most marked changes from old methods, is the placing of the burner at the bottom of the lamp instead of at the top. By this means, the light descends unobstructed by the lamp itself, and illuminates equally in all directions, except directly above, where it can easily be dispensed with. The most prominent of this style of lamp is the Siemen's Lungren Lamp. This lamp previously mentioned in this work, is now manufactured by the Siemens Lungren Co., of Philadelphia, and has been improved and perfected until it is a successful rival to the incandescent electric light. The quality of the light for brilliancy, steadiness and color is unsurpassed. Tests made at the Franklin Institute gave the following results.

Measurement at angle of 45°.		Vertical Measurement candles.	
Candle power of		Candle power of city	
city gas equal to...	17.69 c'd'ls	gas equals to.....	18.60
Gas burned per		Gas burned per hour	
hour (cub ft.)....	16 20	(cubic feet).....	16.00
Candle power..	197.16	Candle power.....	223.86
Candle power per		" " per foot	
foot of gas.....	12.17	of gas.....	13.96

Various attempts have been made to use the gas flame for heating to incandescence some non-combustible substance, and thus competing with the incandescent electric lamp. Notable amongst this style of lamp is the Welsbach incandescent burner. Its construction is as follows :

A hood or mantle, being a net of fine cotton fabric, is impregnated with zirconium or other earth metal in solution, and when dried, and shaped symetrically, is suspended by platinum wires over a Bunsen burner, the whole being enclosed in a glass chimney: When the burner is lighted the combustible portion of the hood is rapidly burned away, leaving a skeleton of zirconium or other metallic oxide—a perfect replica of the original fabric. Under the action of the heat, this delicate surface is brought up to vivid incandescence, though it does not reach its maximum illuminating power for several hours. If not broken by accident it retains its maximum brilliancy for a long, but apparently variable period, depending probably upon a variety of

external, and structural conditions. The weakness of the mantle, and its liability to break easily, has been the greatest difficulty to overcome, but there is no doubt this difficulty can be overcome to a still greater extent than has yet been done.

Leaving this point to the inexorable judgment of actual experience, the results obtained in the laboratory are of special interest, and point to the high value—other conditions being favorable—of the invention.

THE CLAMOND INCANDESCENT GAS LIGHT.—This light first introduced in 1883, since that time remaining dormant, has lately been taken up by eminent English professors, whose competency to pronounce an opinion on any photometrical question cannot be disputed. It is stated on good authority that in pure whiteness, the light surpasses every other form of gas light. Photometrical tests of the appliance show that it will yield a light equal to considerably more than two ordinary burners, and twice that of the Standard Argand burner, with only a slightly increased consumption of gas. It is stated that this system has been applied in a number of large establishments in France, and given general satisfaction, for the economy effected, and the purity of the light afforded.

The principle embodied in this system, is the production of light by the raising to a state of incandescence of a cone of magnesia. Its application does not require any outlay beyond the cost of the burner.

GAS BURNERS.

The proper function of gas is to generate heat, 94 per cent. of the ingredients of gas are consumed in generating heat, and only 6 per cent. producing light.

PREECE.

If this is a true statement, here is a hint of the broad margin there is for improvement in burners.

Gas in its combustion generates enough heat to produce 42 $\frac{1}{2}$ times the light it does.

DR. O'CONNOR SLOANE.

NATURAL GAS.

Natural gas, owing to its low specific gravity (being but little over $\frac{1}{4}$ the weight of air) and extreme tenuity, is exceedingly difficult to confine. If the pipes used to convey it, are not absolutely tight, the gas will escape, and will seek the easiest out-

let to the atmosphere. In Summer it rises through the porous earth, and passes off into the atmosphere, but in Winter when the ground is frozen above the pipes, the gas finds its way along the pipes, and into sewers, and cellars, and owing to its very faint odor, its presence is not discovered, and explosions result.

In cities where natural gas is used, the following method of carrying away the leakage, is used. Over each joint in the mains are placed sleeves, made tight around the pipe at the ends, a pipe is connected with each of these sleeves, and carried to the top of the nearest lamp post, where the gas escapes into the air.

The range of explosibility of natural gas is greater than coal gas, but the resulting explosions are less violent.

Specific gravity .52 air = 1.

COMPOSITION OF NATURAL GAS BY VOLUME.

Carbonic acid.....	none
Heavy hydrocarbons, (Oleflant gas, &c.).....	.50
Carbonic oxide.....	1.00
Oxygen.....	1.30
Light hydrocarbons (CH ₄).....	25.20
Hydrogen.....	2.00
Nitrogen.....	none

Gas taken direct from mains is always dry—allowed to stand over water 24 hours at temperatures 60° Fahr. and Bar. 30° contains in 100 cubic ins. .536 grains water which represents its capacity for water at mean temperatures and pressure.

Specific gravity of dry gas— .520 air = 1.

“ “ gas saturated with water .554.

NATURAL GAS—FINDLAY OHIO.

PERCENTAGE ANALYSIS.

Marsh Gas CH ₄ ..	92.60
Hydrogen H.....	2.18
Carbonic Oxide CO.....	.50
Carbonic acid CO ₂	.26
Ethylene C ₂ H ₄	.31
Nitrogen.....	3.61
Oxygen.....	.34
	99.80

WASTE OF NATURAL GAS.

Speaking of the wasteful manner of using natural gas practiced at Pittsburg and other places where it is plenty, a writer on the spot, says: The consequence is that in four years or less, Pittsburg has probably consumed and wasted gas enough in one way and another, to have lasted forty years, if judiciously burned.

EXPLOSIVE MIXTURES OF AIR AND GAS.

1 volume of natural gas to $\left\{ \begin{array}{l} 9 \text{ vols. of air} \\ 10 \text{ " " " " } \\ 11 \text{ " " " " } \\ 12 \text{ " " " " } \\ 13 \text{ " " " " } \end{array} \right\}$ most explosive.

1 volume of coal gas to $\left\{ \begin{array}{l} 6 \text{ vols. of air} \\ 7 \text{ " " " " } \\ 8 \text{ " " " " } \\ 9 \text{ " " " " } \end{array} \right\}$ most explosive.

REFERENCE TABLES, RULES, Etc.

UNITED STATES STANDARD MEASURES AND WEIGHTS.

MEASURES OF LENGTHS.

The standard measure of length is a brass rod = 1 yard at the temperature of 32° Fahr.

MEASURES OF CAPACITY.

Gallon.—The standard gallon measures 231 cubic inches, and contains 8.3388822 pounds avoirdupois = 58372.1757 grains Troy of distilled water at its maximum density 39.83° Fahr. and 30 ins. barometer.

Bushel.—The standard bushel measures 2150.42 cubic inches = 77.627413 pounds avoirdupois of distilled water at 39.83° Fahr. and 30 inches barometer. Its dimensions are 18½ inches inside diameter, and 8 inches deep; and when heaped the cone must be not less than 6 inches high, equal to 2747.70 cubic inches for a true cone.

Pound.—The standard pound avoirdupois is the weight of 27.7015 cubic inches of distilled water at 39.83° Fahr. and 30 ins. barometer, and weighed in air.

ROPES AND CABLES.

1 cables length = 120 fathoms = 720 feet.

1 fathom = 6 feet.

The Surveyor's chain = 22 yards = 66 feet. It consists of 100 links, and each link = 7.92 inches.

TABLES OF EQUIVALENTS.

MEASURES OF LENGTH.

Miles.	Furlongs	Chains.	Rods.	Yards.	Feet.	Inches.
...	.....	.....	.....	.....	.....	1
...	.....	.....	.....	.....	1	12
...	.....	.....	.....	1	3	36
...	.....	.....	1	5.5	16.5	198
...	.....	1	4	22	66	792
...	1	10	40	220	660	7,920
1	8	80	320	1,760	5,280	63,360

MEASURES OF SURFACE.

Sq. mile	Acres.	Sq. ch'ns	Sq. rods.	Sq. yards.	Sq. feet.	Sq. inches.
.....	.....	.....	.....	.....	.....	1
...	...	...	...	...	1	144
....	....	....	....	1	9	1,296
.....	.....	.....	1	30.25	272.25	39,204
.....	.....	1	16	484	4,356	69,696
.....	1	10	160	4,840	43,560	696,960
1	640	6,400	102,400	3,097,600	27,878,400	4,014,489,600

MEASURES OF CAPACITY.

Cub. yd	Barrels.	Bushels.	Cubic ft.	Pecks.	Gallons.	Cubic inches.
.....	.....	.....	.....	.....	.....	1
....	....	....	....	....	1	231
....	....	....	....	1	2	462
....	....	....	1	3.73809	7.47619	1,728
....	1	1	1 2438	14	8	2150.42
....	1	4.5	4 8125	18	36	8,316
1	5.6103	25.2467	27	100 987	201.974	46,656

MEASURES OF LIQUIDS.

Gallons	Quarts.	Pints.	Gills.	Cubic inches.
.....	.....	.....	.....	1
.....	.....	.....	1	7.2175
.....	.....	1	4	28.875
....	1	2	8	57.75
1	4	8	32	231

MEASURES OF WEIGHTS.

Avoirdupois.

Ton.	Cwt.	Pounds.	Ounces.	Drams.
.....	.....	.....	.....	1
....	....	....	1	16
....	....	1	16	256
....	1	112	1,792	28,672
1	20	2,240	35,840	573,440

TROY.

Pounds.	Ounces.	Dwt.	Grains.	Lb.—Avoirdupois.
.....	.....	.....	.....	1
.....	.....	.....	1	0.00020571
.....	.....	1	24	0.0034285
.....	1	20	480	0.068571
1	12	240	5,760	0.822861

APOTHECARIES.

Pounds.	Ounces.	Drams.	Scruples.	Grains.
.....	.....	.....	.....	1
.....	.....	.....	1	20
.....	.....	1	3	60
.....	1	8	24	480
1	12	96	288	5,760

LONG MEASURE.

12 inches = 1 foot.
 3 feet = 1 yard.
 5½ yards or 16½ feet = 1 rod.
 320 rods = 1 mile.

SQUARE MEASURE.

144 square inches = 1 square ft.
 9 square feet = 1 square yard.
 30½ square yards = 1 square rod.
 160 square rods = 1 acre.
 640 acres = 1 square mile.

CUBIC MEASURE.

1728 cubic inches = 1 cubic foot.
 27 cubic feet = 1 cubic yard.
 16 cubic feet = 1 cord foot.
 8 cord feet = 1 cord.
 128 cubic feet = 1 cord.

LIQUID MEASURE.

4 gills = 1 pint.
 2 pints = 1 quart.
 4 quarts = 1 gallon.
 8½ gallons = 1 barrel.
 63 gallons = 1 hogshead.

The barrel and hogshead are not fixed measures, but vary in different states.

A barrel of kerosene oil contains 42 gallons.

AVOIRDUPOIS WEIGHT.

16 ounces = 1 pound.
 100 pounds = 1 hundredweight.
 20 hundredweight = 1 ton.
 Or 2,000 pounds = 1 ton.
 Long ton = 2,240 pounds.

TROY WEIGHT.

24 grains = 1 pennyweight.
 20 pennyweights = 1 ounce.
 12 ounces = 1 pound.

OTHER DENOMINATIONS IN COMMON USE.

100 lb. of grain or flour = 1 cental 196 lbs. of flour = 1 barrel.
 100 " " Dry Fish = 1 quintal. 200 " " beef or pork = 1 bbl.
 100 " " Nails = 1 keg. 240 " " lime = 1 cask.
 280 lbs. of salt at N. Y. Salt Works = 1 Barrel.

APOTHECARIES' WEIGHT.

20 grains = 1 scruple.
 3 scruples = 1 dram.
 8 drams = 1 ounce.
 12 ounces = 1 pound.

TABLE OF UNITS.

12 units = 1 dozen.
 12 dozen = 1 gross.
 12 gross = 1 great gross.
 20 units = 1 score.

PAPER.

24 sheets = 1 quire.
 20 quires = 1 ream.
 2 reams = 1 bundle.
 5 bundles = 1 bale.

A BOOK FORMED OF SHEETS
FOLIO.

In 2 leaves is called a Folio.
 In 4 leaves is called a Quarto—
 4to.
 In 8 leaves is called an Octavo—
 8vo.
 In 12 leaves is called a Duode-
 cimo—12mo.
 In 16 leaves is called a 16mo.

(ORIGINAL.)

BOARD MEASURE.

The following rule is a very simple one for measuring planks, boards and square timber.

To find the number of feet, board measure, contained in a piece of timber of known dimensions—

RULE.—Multiply the width of the piece by the thickness, both in inches, multiply the product by the length in feet—divide this product by the constant 12, and the quotient will be the number of feet, board measure, which the piece contains.

EXAMPLE 1.—How many feet of board measure does a piece of timber contain, that measures 6 ins. by 9 ins and 20 ft. long?

$$\text{ANSWER.} - \frac{6 \times 9 \times 20}{12} = 90 \text{ feet.}$$

EXAMPLE 2 —How many feet, board measure, does a plank contain, that measures 3 ins. by 15 ins. and 16 ft. long.

$$\text{ANSWER.} - \frac{3 \times 15 \times 16}{12} = 60 \text{ feet.}$$

DIVISIONS OF A FOOT EXPRESSED IN EQUIVALENT DECIMALS.

INCHES.

	0	1	2	3	4	5	6	7	8	9	10	11
0	.00000	.08338	.16666	.25	.33338	.41666	.5	.58338	.66666	.75	.83338	.91666
$\frac{1}{16}$	.00521	.08854	.17187	.25521	.33854	.42187	.50521	.58854	.67187	.75521	.83854	.92187
$\frac{1}{8}$	.01041	.09374	.17707	.26041	.34374	.42707	.51041	.59374	.67707	.76041	.84374	.92707
$\frac{3}{16}$	.01562	.09895	.18228	.26562	.34895	.43228	.51562	.59895	.68228	.76562	.84895	.93228
$\frac{1}{4}$	.02083	.10416	.18750	.27083	.35416	.43750	.52083	.60416	.68750	.77083	.85416	.93750
$\frac{5}{16}$	.02604	.10937	.19270	.27604	.35937	.44270	.52604	.60937	.69270	.77604	.85936	.94270
$\frac{3}{8}$	.03125	.11458	.19791	.28125	.36458	.44791	.53125	.61458	.69791	.78125	.86458	.94791
$\frac{7}{16}$	.03646	.11979	.20312	.28646	.36979	.45312	.53646	.61979	.70312	.78646	.86979	.95312
$\frac{1}{2}$	.04166	.12500	.20832	.29166	.37500	.45833	.54166	.62500	.70832	.79166	.87500	.95833
$\frac{9}{16}$	.04687	.13020	.21353	.29687	.38020	.46353	.54687	.63020	.71353	.79687	.88020	.96353
$\frac{5}{8}$	.05208	.13541	.21874	.30208	.38541	.46875	.55208	.63541	.71874	.80208	.88541	.96875
$\frac{11}{16}$	.05729	.14062	.22395	.30729	.39062	.47395	.55729	.64062	.72395	.80729	.89062	.97395
$\frac{3}{4}$	.06250	.14583	.22916	.31250	.39583	.47916	.56250	.64583	.72916	.81250	.89583	.97916
$\frac{7}{8}$	.06771	.15104	.23437	.31771	.40104	.48437	.56771	.65104	.73437	.81771	.90104	.98437
$\frac{15}{16}$	.07292	.15625	.23958	.32292	.40625	.48958	.57292	.65625	.73958	.82292	.90625	.98958
$\frac{15}{16}$	.07813	.16146	.24479	.32813	.41146	.49479	.57813	.66146	.74479	.82813	.91146	.99479

To find the divisions of an inch expressed in decimals, multiply the above equivalents by 12; for instance, $4\frac{3}{8}$ inches in decimals of a foot = $.34895 \times 12 = 4.1874$ inches.

TABLE OF POLYGONS.

Number of sides in the Polygon.	Centre Angle α .	Polygon Angle ϕ .	Side = $h R$.	Area = $h S^2$.	Apothem = $h R$.	Side = $h r$.	Area = $h^2 s$.
Trigon.	3 120°	60°	1.732	0.4330	0.5000	3.4641	5.1961
Tetragon.	4 90°	90°	1.4142	1.0000	0.7071	2.0000	4.0000
Pentagon.	5 72°	108°	1.1755	1.7205	0.8090	1.4536	3.6327
Hexagon.	6 60°	120°	1.0000	2.5980	0.8660	1.1547	3.4640
Heptagon.	7 51°43'	128°17'	0.8677	3.6339	0.9009	0.9631	3.3710
Octagon.	8 45°	135°	0.7653	4.8284	0.9238	0.8284	3.3139
Nonagon.	9 40°	140°	0.6840	6.1820	0.9396	0.7279	3.2756
Decagon.	10 36°	144°	0.6180	7.6942	0.9510	0.6498	3.2490
Undecagon.	11 32°13'	147°47'	0.5634	9.3656	0.9595	0.5872	3.2290
Dodecagon.	12 30°	150°	0.5176	11.196	0.9659	0.5359	3.2152
	14 25°43'	154°17'	0.4450	15.334	0.9762	0.4562	3.1935
	15 24°	156°	0.4158	17.642	0.9781	0.4250	3.1882
	16 22°30'	157°30'	0.3901	20.128	0.9807	0.3978	3.1824
	18 20°	160°	0.3472	25.534	0.9848	0.3526	3.1737
	20 18°	162°	0.3130	40.634	0.9877	0.3166	3.1676
	24 15°	165°	0.2610	45.593	0.9914	0.2632	3.1596

Explanation of the Table for Polygons.

The number of sides in the polygon is noted in the first column.

k = tabular coefficient, to be multiplied as noted on the top of the columns.

Example 1. How long is the side of an inscribed Pentagon, when the radius of the circle is 3 feet, and 4 inches? (4 inches = 0.333 feet.)

$3.333 \times 1.1755 = 3.9179$ feet, the answer.

Example 2. What is the area of a Heptagon when one of its sides is 13.75 inches

$13.75 \times 3.6339 = 687.02$ square inches.

VOLUME OF A CONE.

Multiply the area of base by the perpendicular height, and take one-third of the product.

SURFACE OF A CONE.

Multiply the circumference of the base by the slant height or side of cone, and take one-half of the product.

SURFACE OF FRUSTRUM OF A CONE.

Multiply the sum of the circumference of the two ends by the slant height, and take one-half the product.

VOLUME OF THE FRUSTRUM OF A CONE.

Add together the squares of the diameters of the two ends and the product of the two diameters—multiply this sum by .7854 and this product by the perpendicular height, and divide by 8

TO COMPUTE THE SURFACE OF A SPHERE.

Multiply the diameter by the circumference, and the product will give the surface.

To compute the length of an arc, when the chord and height of the arc are given—

From 8 times the chord of half the arc, take the chord of the whole arc, and one-third the remainder will be the length of the arc.

To find the radius of an arc, when the chord and height of the arc are given—

Radius = the sum of the square of half the chord and the square of the height, divided by twice the height.

PROPERTIES OF THE CIRCLE.

The periphery of a circle is divided into 360° (degrees) equal parts.

One degree = $60'$ (minutes) r = radius of the circle.

One minute = $60''$ (seconds) d = diameter of the circle.

a = area of the circle.

p = periphery or circumference of the circle.

Half a circle = 180° . The *Greek* letter $\pi = 3,14159 +$ when $d = 1$.

Quarter of a circle, or quadrant = 90° .

FORMULA FOR THE CIRCLE.

$$p = \pi d = 3.14d \dots\dots 1$$

$$p = 2\pi r = 6.28r \dots\dots 2$$

$$p = 2\sqrt{\pi a} = 3.54\sqrt{a} \dots\dots 3$$

$$d = \frac{p}{\pi} = \frac{p}{3.14} \dots\dots 4$$

$$d = 2\sqrt{\frac{a}{\pi}} = 1.128\sqrt{a} \dots\dots 5$$

$$r = \frac{p}{2\pi} = \frac{p}{6.28} \dots\dots 6$$

$$\pi = 3,141592653 +$$

$$r = \frac{\sqrt{a}}{\pi} = 0.564\sqrt{a} \dots\dots 7$$

$$a = \frac{\pi d^2}{4} = 0.785d^2 \dots\dots 8$$

$$a = \pi r^2 = 3.14r^2 \dots\dots 9$$

$$a = \frac{p^2}{4\pi} = \frac{p^2}{12.56} \dots\dots 10$$

$$a = \frac{pr}{2} = \frac{pd}{4} \dots\dots 11$$

$$a = \frac{\pi rd}{2} = 1.57rd \dots\dots 12$$

USEFUL FACTORS.

In which p represents the circumference of a circle, the radius = 1.

$p = \dots$	3.141592653 +	$\frac{1}{15}p = \dots\dots\dots$	.261799
$2p = \dots$	6.283185307 +	$\frac{1}{80}p = \dots\dots\dots$	.008727
$4p = \dots$	12.566370614 +	$\frac{1}{3}\sqrt{p} = \dots\dots\dots$	.882626
$\frac{1}{2}p = \dots$	1.570796326 +	$36p = \dots\dots\dots$	113.097335
$\frac{1}{4}p = \dots$	.785398163 +	$p_2 = (3.14_6) = \dots$	9.8596
$\frac{1}{8}p = \dots$	4.18879	$p_3 = \dots\dots\dots$	30.959144
$\frac{1}{16}p = \dots$	.523598	$\sqrt{p} = \dots\dots\dots$	1.772452
$\frac{1}{32}p = \dots$	.392699		

APPROXIMATE MULTIPLIERS FOR FACILITATING CALCULATIONS.

Square inch $\times .007$ = square feet.

" feet $\times .111$ = " yards.

" yards $\times .0002067$ = statute acres.

" feet $\times 183.346$ = circular inches.

Circular inches $\times .00456$ = square feet.

Links $\times .22$ = yards

" $\times .66$ = feet.

Feet $\times 1.5$ = links.

Cubic inches $\times .00058$ = cubic feet.

" feet $\times .307$ = cubic yards.

" " $\times 2200$ = cylindrical inches.

Cylindrical inches $\times .0004546$ = cubic yards.

" feet $\times .02909$ = cubic yards.

Cubic feet $\times .779$ = bushels.

" inches $\times .00045$ = bushels.

Bushels $\times .0476$ = cubic yards.

" $\times 1.284$ = " feet.

" $\times 2218.2$ = " inches.

Lineal feet $\times .00019$ statute miles.

" yards $\times .0006$ " "

Pounds avoirdupois $\times 7000$ = grains.

Grains $\times .0001429$ = pounds avoirdupois.

Pounds avoirdupois $\times .009$ = cwts.

“ “ $\times .00045$ = tons.

Tons $\times 2240$ = pounds avoirdupois.

Pounds on the square inch $\times 144$ = pounds on the square foot.

Pounds on the square foot $\times .007$ = pounds on the square inch.

Miles per hour $\times 1.467$ = feet per second.

Feet per second $\times .682$ = miles per hour.

French metres $\times 3.281$ = English feet.

Diameter of a circle $\times 3.1416$ = the circumference.

Circumference of a circle $\times .31831$ = the diameter.

Diameter of a circle $\times .8862$ = the side of an equal square.

“ “ “ $\times 7071$ = “ “ “ “ inscribed “

Side of a square $\times 1.128$ = the diameter of an equal circle.

Square of diameter $\times .7854$ = the area of a circle.

“ root of area $\times 1.12837$ = the diameter of equal circle.

“ of the diameter of a sphere $\times 3.1416$ = convex surface.

Cube of the “ “ “ “ $\times .5236$ = solidity.

One atmosphere = 14.7 lbs. on the square inch,

“ “ = 2116 “ “ “ “ foot.

“ “ = 29.922 inches of mercury.

“ “ = 33.9 “ “ water.

Each 1000 cubic feet of coal gas in a holder $\times 40$ = weight of gas in pounds.

SOLUTION OF TRIANGLES.

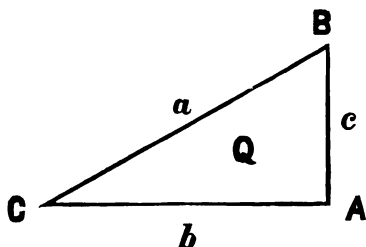
REFERENCE.

a—b—c = length of sides.

A—B—C. Angles opposite to a—b—c—respectively

Q = area.

RIGHT-ANGLED TRIANGLE.



$$a = \sqrt{b^2 + c^2}$$

$$b = a \cos C.$$

$$c = a \sin C.$$

$$a = \frac{b}{\sin B}$$

$$b = c \cot C.$$

$$c = \frac{b}{\cot C}.$$

$$a = \frac{c}{\sin C}$$

$$b = a \sin B.$$

$$c = \frac{b}{\tan B}$$

$$a = \frac{b}{\cos C}$$

$$b = c \tan B$$

$$c = b \tan C$$

$$a = \frac{2\sqrt{a}}{\sin 2C}$$

$$\tan C = \frac{c}{b}$$

$$\tan C = \frac{\sin C}{\cos C}$$

$$\cot C = \frac{\cos C}{\sin C}$$

$$\tan C = \frac{1}{\cot C}$$

$$\cot C = \frac{1}{\tan C}$$

$$\sec C = \frac{1}{\cos C}$$

$$\operatorname{cosec} C = \frac{1}{\sin C}$$

$$\cos C = \frac{b}{a}$$

$$\sin C = \frac{c}{a}$$

$$\cos C = \sin B$$

$$\tan B = \frac{b}{c}$$

$$\sin B = \frac{b}{a}$$

$$\sin 2C = \frac{4Q}{a^2}$$

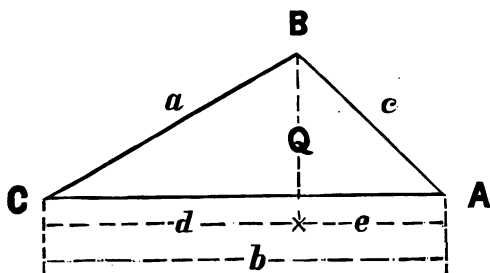
$$\tan C = \frac{2Q}{b^2}$$

$$a^2 = b^2 + c^2$$

$$b = \sqrt{a^2 - c^2}$$

$$c = \sqrt{a^2 - b^2}$$

OBLIQUE ANGLED TRIANGLES.



$$a = \frac{C \sin A}{\sin C}$$

$$b = \frac{C \sin B}{\sin C}$$

$$\sin C = \frac{C \sin B}{b}$$

$$a = \frac{C \sin A}{\sin (A + B)}$$

$$b = \frac{2Q}{c \sin A}$$

$$\sin C = \frac{C \sin A}{a}$$

$$a = \frac{2Q}{b \sin C}$$

$$a = \sqrt{b^2 \times c^2 - 2bc \cos A} \quad \sin A = \frac{2Q}{bc}$$

$$d = \frac{1}{2} 2 \left(b + \frac{(a+c)(a-c)}{b} \right) \sin A = \frac{a \sin C}{C}$$

$$e = \frac{1}{2} \left(b - \frac{(a \times c)(a-c)}{b} \right) \quad Q = \frac{bc \sin A}{2} \quad Q = \frac{ab \sin C}{2}$$

$$c = \sqrt{\frac{2Q \sin C}{\sin A \sin (A + C)}} \quad a : b = \sin A : \sin B \quad b : c = \sin B : \sin C$$

$$a : c = \sin A : \sin C \quad Q : ab = \sin C : 2$$

A triangle contains seven quantities, namely, three sides, three angles and the surface or enclosed area. When three of these quantities are given (the area or one side must be one of them) the four remaining ones, can by them be ascertained, and the operation is called *solving the triangle*.

For a description, and explanation of the trigonometrical functions, which would be too long to insert here, the student is referred to any good work on Trigonometry, or to Nystrom's Mechanics. Tables of Natural Sines, Cosines, Tangents, Cotangents, Secants and Co-secants are given calculated to every 10 minutes of the circle by which it is possible to solve triangles without a knowledge of Trigonometry—which is done by exchanging the letters in the formula, for the proper figures in the tables, and carrying out the operations according to the algebraic signs.

A few examples will show how this is done, more clearly. **Example 1.** The side a of a right angle triangle, = 25 feet, and the angle $C = 30^\circ 5'$ what are the length of the sides b and c . As we have the value of a and the angle C , we look for a formula to suit, and find $c = a \sin C$, substituting the value of the letters and obtaining the sine of the angle C from the table of natural sines, we have $c = 25 \times .50126 = 12.5315$ ft. Again we find the value of b to be $b = a \cos C$, substituting value of a , and $\cos C$ from table we have $b = 25 \times .8658 = 21.6325$ ft.

EXAMPLE 2.—In calculating the dimensions of a roof we find the half span is 30 ft. length of rafter 34,641, and height 17.32 ft. to find the angle C .

Among the formula we find $\tan C = \frac{c}{b}$ substituting as before we have $17.32 \div 34,641 = .5773$ which we find to be the tangent of 30 degrees.

EXAMPLE 3.—The side c of a right-angled triangle is 365 ft. and the angle $C = 39^\circ 20'$. How long is the side a ? $a = \frac{c}{\sin C}$

$$= \frac{365}{\sin 39^\circ 20'} = \frac{365}{0.63383} = 575.86 \text{ ft. the answer.}$$

TRIGONOMETRY.

NATURAL SINE.

Deg.	0'	10'	20'	30'	40'	50'	60'	
0	.00000	.00291	.00581	.00872	.01163	.01454	.01745	89
1	.01745	.02036	.02326	.02617	.02908	.03199	.03489	88
2	.03489	.03780	.04071	.04361	.04652	.04943	.05233	87
3	.05233	.05524	.05814	.06104	.06395	.06685	.06975	86
4	.06975	.07265	.07555	.07845	.08135	.08425	.08715	85
5	.08715	.09005	.09294	.09584	.09874	.10163	.10453	84
6	.10453	.10742	.11031	.11320	.11609	.11898	.12188	83
7	.12188	.12477	.12764	.13052	.13340	.13629	.13917	82
8	.13917	.14205	.14493	.14780	.15068	.15356	.15643	81
9	.15643	.15930	.16217	.16504	.16791	.17078	.17364	80
10	.17364	.17651	.17937	.18223	.18509	.18795	.19080	79
11	.19080	.19366	.19651	.19936	.20221	.20506	.20791	78
12	.20791	.21075	.21359	.21643	.21927	.22211	.22495	77
13	.22495	.22778	.23061	.23344	.23627	.23909	.24192	76
14	.24192	.24474	.24756	.25038	.25319	.25600	.25881	75
15	.25881	.26162	.26443	.26723	.27004	.27284	.27563	74
16	.27563	.27843	.28123	.28401	.28680	.28958	.29237	73
17	.29237	.29515	.29793	.30070	.30347	.30624	.30901	72
18	.30901	.31178	.31454	.31730	.32006	.32281	.32556	71
19	.32556	.32831	.33106	.33380	.33654	.33928	.34202	70
20	.34202	.34475	.34748	.35020	.35293	.35565	.35836	69
21	.35836	.36108	.36379	.36650	.36920	.37190	.37460	68
22	.37460	.37730	.37999	.38268	.38536	.38805	.39073	67
23	.39073	.39340	.39607	.39874	.40141	.40407	.40673	66
24	.40673	.40939	.41204	.41469	.41733	.41998	.42261	65
25	.42261	.42525	.42788	.43051	.43313	.43575	.43837	64
26	.43837	.44098	.44359	.44619	.44879	.45139	.45398	63
27	.45398	.45658	.45916	.46174	.46432	.46690	.46947	62
28	.46947	.47203	.47460	.47715	.47971	.48226	.48480	61
29	.48480	.48735	.48988	.49242	.49495	.49747	.50000	60
30	.50000	.50251	.50502	.50753	.51004	.51254	.51503	59
31	.51503	.51752	.52001	.52249	.52497	.52745	.52991	58
32	.52991	.53238	.53484	.53729	.53975	.54219	.54463	57
33	.54463	.54707	.54950	.55193	.55436	.55677	.55919	56
34	.55919	.56160	.56400	.56640	.56880	.57119	.57357	55
35	.57357	.57595	.57833	.58070	.58306	.58542	.58778	54
36	.58778	.59013	.59248	.59482	.59715	.59948	.60181	53
37	.60181	.60413	.60645	.60876	.61106	.61336	.61566	52
38	.61566	.61795	.62023	.62251	.62478	.62705	.62932	51
39	.62932	.63157	.63383	.63607	.63832	.64055	.64278	50
40	.64278	.64501	.64723	.64944	.65165	.65386	.65605	49
41	.65605	.65825	.66043	.66262	.66479	.66696	.66913	48
42	.66913	.67128	.67344	.67559	.67773	.67986	.68199	47
43	.68199	.68412	.68624	.68835	.69046	.69256	.69465	46
44	.69465	.69674	.69883	.70090	.70296	.70504	.70710	45
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COSINE.

TRIGONOMETRY.

NATURAL SINE.

Deg.	0'	10'	20'	30'	40'	50'	60'	
45	.70710	.70916	.71120	.71325	.71528	.71731	.71933	44
46	.71933	.72135	.72336	.72537	.72737	.72935	.73135	43
47	.73135	.73333	.73530	.73727	.73923	.74119	.74314	42
48	.74314	.74508	.74702	.74895	.75088	.75279	.75470	41
49	.75470	.75661	.75851	.76040	.76229	.76417	.76604	40
50	.76604	.76791	.76977	.77162	.77347	.77531	.77714	39
51	.77714	.77897	.78079	.78260	.78441	.78621	.78801	38
52	.78801	.78979	.79157	.79335	.79512	.79688	.79863	37
53	.79863	.80038	.80212	.80385	.80558	.80730	.80901	36
54	.80901	.81072	.81242	.81411	.81580	.81748	.81915	35
55	.81915	.82081	.82247	.82412	.82577	.82740	.82903	34
56	.82903	.83066	.83227	.83388	.83548	.83708	.83867	33
57	.83867	.84025	.84182	.84339	.84495	.84650	.84804	32
58	.84804	.84958	.85111	.85264	.85415	.85566	.85716	31
59	.85716	.85866	.86014	.86162	.86310	.86456	.86602	30
60	.86602	.86747	.86891	.87035	.87178	.87320	.87461	29
61	.87461	.87602	.87742	.87881	.88020	.88157	.88294	28
62	.88294	.88430	.88566	.88701	.88835	.88968	.89100	27
63	.89100	.89232	.89363	.89493	.89622	.89751	.89879	26
64	.89879	.90006	.90132	.90258	.90383	.90507	.90630	25
65	.90630	.90753	.90875	.90996	.91116	.91235	.91354	24
66	.91354	.91472	.91589	.91706	.91811	.91926	.92050	23
67	.92050	.92163	.92276	.92387	.92498	.92609	.92718	22
68	.92718	.92826	.92934	.93041	.93147	.93253	.93358	21
69	.93358	.93461	.93564	.93667	.93768	.93869	.93969	20
70	.93969	.94068	.94166	.94264	.94360	.94456	.94551	19
71	.94551	.94646	.94739	.94832	.94924	.95015	.95105	18
72	.95105	.95195	.95283	.95371	.95458	.95545	.95630	17
73	.95630	.95715	.95799	.95881	.95964	.96045	.96126	16
74	.96126	.96205	.96284	.96363	.96440	.96516	.96592	15
75	.96592	.96667	.96741	.96814	.96887	.96958	.97029	14
76	.97029	.97099	.97168	.97236	.97304	.97361	.97427	13
77	.97427	.97492	.97556	.97629	.97692	.97753	.97814	12
78	.97814	.97874	.97934	.97992	.98050	.98106	.98162	11
79	.98162	.98217	.98272	.98325	.98378	.98429	.98480	10
80	.98480	.98530	.98580	.98628	.98676	.98722	.98768	9
81	.98768	.98813	.98858	.98901	.98944	.98985	.99026	8
82	.99026	.99066	.99106	.99144	.99182	.99218	.99254	7
83	.99254	.99289	.99323	.99357	.99389	.99421	.99453	6
84	.99453	.99482	.99511	.99539	.99567	.99593	.99619	5
85	.99619	.99644	.99668	.99691	.99714	.99735	.99756	4
86	.99756	.99776	.99795	.99813	.99830	.99847	.99863	3
87	.99863	.99877	.99891	.99904	.99917	.99928	.99939	2
88	.99939	.99948	.99957	.99965	.99972	.99979	.99984	1
89	.99984	.99989	.99993	.99996	.99998	.99999	1.0000	0
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COSINE.

TRIGONOMETRY.

NATURAL TANGENT.

Deg.	0'	10'	20'	30'	40'	50'	60'	
0	.00000	.00290	.00581	.00872	.01163	.01454	.01745	89
1	.01745	.02036	.02327	.02618	.02909	.03200	.03492	88
2	.03492	.03783	.04074	.04366	.04657	.04949	.05240	87
3	.05240	.05532	.05824	.06116	.06408	.06700	.06992	86
4	.06992	.07285	.07577	.07870	.08162	.08455	.08748	85
5	.08748	.09042	.09335	.09628	.09922	.10216	.10510	84
6	.10510	.10804	.11098	.11393	.11688	.11983	.12278	83
7	.12278	.12573	.12869	.13165	.13461	.13757	.14054	82
8	.14054	.14350	.14647	.14945	.15242	.15540	.15838	81
9	.15838	.16136	.16435	.16734	.17033	.17332	.17632	80
10	.17632	.17932	.18233	.18533	.18834	.19136	.19438	79
11	.19438	.19740	.20042	.20345	.20648	.20951	.21255	78
12	.21255	.21559	.21864	.22169	.22474	.22780	.23086	77
13	.23086	.23393	.23700	.24007	.24315	.24624	.24932	76
14	.24932	.25242	.25551	.25861	.26172	.26483	.26794	75
15	.26794	.27106	.27419	.27732	.28045	.28359	.28674	74
16	.28674	.28989	.29305	.29621	.29938	.30255	.30573	73
17	.30573	.30891	.31210	.31529	.31849	.32169	.32491	72
18	.32491	.32813	.33136	.33459	.33783	.34107	.34432	71
19	.34432	.34758	.35084	.35411	.35739	.36067	.36397	70
20	.36397	.36726	.37057	.37388	.37720	.38053	.38386	69
21	.38386	.38720	.39055	.39391	.39727	.40064	.40402	68
22	.40402	.40741	.41080	.41421	.41762	.42104	.42447	67
23	.42447	.42791	.43135	.43481	.43827	.44174	.44522	66
24	.44522	.44871	.45221	.45572	.45924	.46277	.46630	65
25	.46630	.46985	.47340	.47697	.48055	.48413	.48773	64
26	.48773	.49133	.49495	.49858	.50221	.50586	.50952	63
27	.50952	.51319	.51687	.52056	.52426	.52798	.53170	62
28	.53170	.53544	.53919	.54295	.54672	.55051	.55430	61
29	.55430	.55811	.56193	.56577	.56961	.57347	.57735	60
30	.57735	.58123	.58513	.58904	.59296	.59690	.60086	59
31	.60086	.60482	.60880	.61280	.61680	.62083	.62486	58
32	.62486	.62892	.63298	.63707	.64116	.64527	.64940	57
33	.64940	.65355	.65771	.66188	.66607	.67028	.67450	56
34	.67450	.67874	.68300	.68728	.69157	.69588	.70020	55
35	.70020	.70455	.70891	.71329	.71769	.72210	.72654	54
36	.72654	.73099	.73546	.73996	.74447	.74900	.75355	53
37	.75355	.75812	.76271	.76732	.77195	.77661	.78128	52
38	.78128	.78598	.79069	.79543	.80019	.80497	.80978	51
39	.80978	.81461	.81946	.82433	.82923	.83415	.83909	50
40	.83909	.84406	.84906	.85408	.85912	.86414	.86928	49
41	.86928	.87440	.87955	.88472	.88992	.89515	.90040	48
42	.90040	.90568	.91099	.91633	.92169	.92704	.93251	47
43	.93251	.93796	.94345	.94896	.95450	.96008	.96568	46
44	.96568	.97132	.97699	.98269	.98843	.99419	1.0000	45
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COTANGENT.

TRIGONOMETRY.

NATURAL TANGENT.

Deg.	0'	10'	20'	30'	40'	50'	60'	
45	1.0000	1.0058	1.0117	1.0176	1.0235	1.0295	1.0355	44
46	1.0355	1.0415	1.0476	1.0537	1.0599	1.0661	1.0723	43
47	1.0723	1.0786	1.0849	1.0913	1.0977	1.1041	1.1106	42
48	1.1106	1.1171	1.1236	1.1302	1.1369	1.1436	1.1503	41
49	1.1503	1.1571	1.1639	1.1708	1.1777	1.1847	1.1917	40
50	1.1917	1.1988	1.2059	1.2130	1.2203	1.2275	1.2348	39
51	1.2348	1.2422	1.2496	1.2571	1.2647	1.2722	1.2799	38
52	1.2799	1.2876	1.2954	1.3032	1.3111	1.3190	1.3270	37
53	1.3270	1.3351	1.3432	1.3514	1.3596	1.3679	1.3763	36
54	1.3763	1.3848	1.3933	1.4019	1.4106	1.4193	1.4281	35
55	1.4281	1.4370	1.4459	1.4550	1.4641	1.4732	1.4825	34
56	1.4825	1.4919	1.5013	1.5108	1.5201	1.5301	1.5398	33
57	1.5398	1.5497	1.5596	1.5696	1.5795	1.5900	1.6003	32
58	1.6003	1.6107	1.6212	1.6318	1.6425	1.6533	1.6642	31
59	1.6642	1.6752	1.6864	1.6976	1.7090	1.7204	1.7320	30
60	1.7320	1.7437	1.7555	1.7674	1.7795	1.7917	1.8040	29
61	1.8040	1.8164	1.8290	1.8417	1.8546	1.8676	1.8807	28
62	1.8807	1.8939	1.9074	1.9209	1.9347	1.9485	1.9626	27
63	1.9626	1.9768	1.9911	2.0056	2.0203	2.0352	2.0503	26
64	2.0503	2.0655	2.0809	2.0965	2.1123	2.1283	2.1445	25
65	2.1445	2.1608	2.1774	2.1942	2.2113	2.2285	2.2460	24
66	2.2460	2.2637	2.2816	2.2998	2.3182	2.3369	2.3558	23
67	2.3558	2.3750	2.3944	2.4142	2.4342	2.4545	2.4750	22
68	2.4750	2.4959	2.5171	2.5386	2.5604	2.5826	2.6050	21
69	2.6050	2.6279	2.6510	2.6746	2.6985	2.7228	2.7474	20
70	2.7474	2.7725	2.7980	2.8239	2.8502	2.8769	2.9042	19
71	2.9042	2.9318	2.9600	2.9886	3.0178	3.0474	3.0776	18
72	3.0776	3.1084	3.1397	3.1715	3.2040	3.2371	3.2708	17
73	3.2708	3.3052	3.3402	3.3759	3.4123	3.4495	3.4874	16
74	3.4874	3.5260	3.5655	3.6058	3.6470	3.6890	3.7320	15
75	3.7320	3.7759	3.8208	3.8667	3.9136	3.9616	4.0107	14
76	4.0107	4.0610	4.1125	4.1652	4.2193	4.2747	4.3314	13
77	4.3314	4.3896	4.4494	4.5107	4.5736	4.6382	4.7046	12
78	4.7046	4.7728	4.8430	4.9151	4.9894	5.0658	5.1445	11
79	5.1445	5.2256	5.3092	5.3955	5.4845	5.5763	5.6712	10
80	5.6712	5.7693	5.8708	5.9757	6.0844	6.1970	6.3137	9
81	6.3137	6.4348	6.5605	6.6911	6.8269	6.9682	7.1153	8
82	7.1153	7.2687	7.4287	7.5957	7.7703	7.9580	8.1448	7
83	8.1448	8.3449	8.5555	8.7768	9.0098	9.2553	9.5143	6
84	9.5143	9.7881	10.078	10.385	10.711	11.059	11.430	5
85	11.430	11.826	12.250	12.760	13.196	13.726	14.300	4
86	14.300	14.924	15.604	16.349	17.169	18.074	19.081	3
87	19.081	20.205	21.470	22.003	24.541	26.431	28.686	2
88	28.686	31.241	34.367	38.188	42.964	49.103	57.289	1
89	57.289	68.750	85.939	114.58	171.88	343.77	∞	0
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COTANGENT.

TRIGONOMETRY.

NATURAL SECANT.

Deg.	0'	10'	20'	30'	40'	50'	60'	
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001	1.0001	89
1	1.0001	1.0002	1.0002	1.0003	1.0004	1.0005	1.0006	88
2	1.0006	1.0007	1.0008	1.0009	1.0010	1.0012	1.0013	87
3	1.0013	1.0015	1.0016	1.0018	1.0020	1.0022	1.0024	86
4	1.0024	1.0026	1.0028	1.0031	1.0033	1.0035	1.0038	85
5	1.0038	1.0040	1.0043	1.0046	1.0049	1.0052	1.0055	84
6	1.0055	1.0058	1.0061	1.0064	1.0068	1.0071	1.0075	83
7	1.0075	1.0078	1.0082	1.0086	1.0090	1.0094	1.0098	82
8	1.0098	1.0102	1.0106	1.0111	1.0115	1.0120	1.0124	81
9	1.0124	1.0129	1.0134	1.0139	1.0144	1.0149	1.0154	80
10	1.0154	1.0159	1.0164	1.0170	1.0175	1.0181	1.0187	79
11	1.0187	1.0192	1.0198	1.0204	1.0210	1.0217	1.0223	78
12	1.0223	1.0229	1.0236	1.0242	1.0249	1.0256	1.0263	77
13	1.0263	1.0269	1.0277	1.0284	1.0291	1.0298	1.0306	76
14	1.0306	1.0313	1.0321	1.0329	1.0336	1.0344	1.0352	75
15	1.0352	1.0360	1.0369	1.0377	1.0385	1.0394	1.0403	74
16	1.0403	1.0411	1.0420	1.0429	1.0438	1.0447	1.0456	73
17	1.0456	1.0466	1.0475	1.0485	1.0494	1.0504	1.0514	72
18	1.0514	1.0524	1.0534	1.0544	1.0555	1.0565	1.0576	71
19	1.0576	1.0586	1.0597	1.0608	1.0619	1.0630	1.0641	70
20	1.0641	1.0653	1.0664	1.0676	1.0687	1.0699	1.0711	69
21	1.0711	1.0723	1.0735	1.0747	1.0760	1.0772	1.0785	68
22	1.0785	1.0798	1.0810	1.0823	1.0837	1.0850	1.0863	67
23	1.0863	1.0877	1.0890	1.0904	1.0918	1.0932	1.0946	66
24	1.0946	1.0960	1.0974	1.0989	1.1004	1.1018	1.1033	65
25	1.1033	1.1048	1.1063	1.1079	1.1094	1.1110	1.1126	64
26	1.1126	1.1141	1.1157	1.1174	1.1190	1.1206	1.1223	63
27	1.1223	1.1239	1.1256	1.1273	1.1290	1.1308	1.1325	62
28	1.1325	1.1343	1.1361	1.1378	1.1396	1.1415	1.1433	61
29	1.1433	1.1452	1.1470	1.1489	1.1508	1.1527	1.1547	60
30	1.1547	1.1566	1.1586	1.1605	1.1625	1.1646	1.1666	59
31	1.1666	1.1686	1.1707	1.1728	1.1749	1.1770	1.1791	58
32	1.1791	1.1833	1.1835	1.1856	1.1878	1.1901	1.1923	57
33	1.1923	1.1946	1.1969	1.1992	1.2015	1.2038	1.2062	56
34	1.2062	1.2085	1.2109	1.2134	1.2158	1.2182	1.2207	55
35	1.2207	1.2232	1.2257	1.2283	1.2308	1.2334	1.2360	54
36	1.2360	1.2386	1.2413	1.2440	1.2466	1.2494	1.2521	53
37	1.2521	1.2548	1.2576	1.2604	1.2632	1.2661	1.2690	52
38	1.2690	1.2719	1.2748	1.2777	1.2807	1.2837	1.2867	51
39	1.2867	1.2898	1.2928	1.2959	1.2990	1.3022	1.3054	50
40	1.3054	1.3086	1.3118	1.3150	1.3183	1.3216	1.3250	49
41	1.3250	1.3283	1.3317	1.3351	1.3386	1.3421	1.3456	48
42	1.3456	1.3491	1.3527	1.3563	1.3599	1.3636	1.3673	47
43	1.3673	1.3710	1.3748	1.3785	1.3824	1.3862	1.3901	46
44	1.3901	1.3940	1.3980	1.4020	1.4060	1.4101	1.4142	45
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COSECANT.

TRIGONOMETRY.

NATURAL SECANT.

Deg.	0'	10'	20'	30'	40'	50'	60'	
45	1.4142	1.4183	1.4225	1.4267	1.4309	1.4352	1.4395	44
46	1.4395	1.4439	1.4483	1.4527	1.4572	1.4617	1.4662	43
47	1.4662	1.4708	1.4755	1.4801	1.4849	1.4896	1.4944	42
48	1.4944	1.4993	1.5042	1.5091	1.5141	1.5191	1.5242	41
49	1.5242	1.5293	1.5345	1.5397	1.5450	1.5503	1.5557	40
50	1.5557	1.5611	1.5666	1.5721	1.5777	1.5833	1.5890	39
51	1.5890	1.5947	1.6005	1.6063	1.6122	1.6182	1.6242	38
52	1.6242	1.6303	1.6364	1.6426	1.6489	1.6552	1.6616	37
53	1.6616	1.6680	1.6745	1.6811	1.6878	1.6945	1.7013	36
54	1.7013	1.7081	1.7150	1.7220	1.7291	1.7362	1.7434	35
55	1.7434	1.7507	1.7580	1.7655	1.7730	1.7806	1.7882	34
56	1.7882	1.7960	1.8038	1.8118	1.8198	1.8278	1.8360	33
57	1.8360	1.8443	1.8527	1.8611	1.8697	1.8783	1.8870	32
58	1.8870	1.8959	1.9048	1.9138	1.9230	1.9322	1.9416	31
59	1.9416	1.9510	1.9606	1.9702	1.9800	1.9899	2.0000	30
60	2.0000	2.0101	2.0203	2.0307	2.0412	2.0519	2.0626	29
61	2.0626	2.0735	2.0845	2.0957	2.1070	2.1184	2.1300	28
62	2.1300	2.1417	2.1536	2.1656	2.1778	2.1901	2.2026	27
63	2.2026	2.2153	2.2281	2.2411	2.2543	2.2676	2.2811	26
64	2.2811	2.2948	2.3087	2.3228	2.3370	2.3515	2.3662	25
65	2.3662	2.3810	2.3961	2.4114	2.4269	2.4426	2.4585	24
66	2.4585	2.4747	2.4911	2.5078	2.5247	2.5418	2.5593	23
67	2.5593	2.5769	2.5949	2.6131	2.6316	2.6503	2.6694	22
68	2.6694	2.6888	2.7085	2.7285	2.7488	2.7694	2.7904	21
69	2.7904	3.8117	2.8334	2.8554	2.8778	2.9006	2.9238	20
70	2.9238	2.9473	2.9713	2.9957	3.0205	3.0458	3.0715	19
71	3.0715	3.0977	3.1243	3.1515	3.1791	3.2073	3.2360	18
72	3.2360	3.2653	3.2951	3.3255	3.3564	3.3880	3.4203	17
73	3.4203	3.4531	3.4867	3.5209	3.5558	3.5915	3.6279	16
74	3.6279	3.6651	3.7031	3.7419	3.7816	3.8222	3.8637	15
75	3.8637	3.9061	3.9495	3.9939	4.0393	4.0859	4.1335	14
76	4.1335	4.1823	4.2323	4.2836	4.3362	4.3900	4.4454	13
77	4.4454	4.5021	4.5604	4.6202	4.6816	4.7448	4.8097	12
78	4.8097	4.8764	4.9451	5.0158	5.0886	5.1635	5.2406	11
79	5.2406	5.3204	5.4026	5.4874	5.5749	5.6653	5.7587	10
80	5.7587	5.8553	5.9553	6.0588	6.1660	6.2771	6.3924	9
81	6.3924	6.5120	6.6363	6.7654	6.8997	7.0396	7.1852	8
82	7.1852	7.3371	7.4957	7.6612	7.8344	8.0156	8.2055	7
83	8.2055	8.4046	8.6137	8.8336	9.0651	9.3091	9.5667	6
84	9.5667	9.8391	10.127	10.437	10.758	11.104	11.473	5
85	11.473	11.868	12.291	12.745	13.224	13.723	14.235	4
86	14.235	14.957	15.636	16.380	17.198	18.102	19.107	3
87	19.107	20.230	21.493	22.925	24.562	26.450	28.653	2
88	28.653	31.257	34.382	38.201	42.975	49.114	57.298	1
89	57.298	68.757	85.945	114.59	171.88	343.77	∞	0
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COSECANT.

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circ.	Area.	Diameter.	Circ.	Area.	Diameter.	Circ.	Area.
								
$\frac{1}{32}$	0.0981	0.00076	5	15.70	19.635	.11	34.55	95.033
$\frac{1}{16}$	1.963	.00306		16.10	20.629		34.95	97.205
$\frac{3}{32}$	3.926	0.1227	$\frac{1}{4}$	16.49	21.647	$\frac{1}{4}$	35.34	99.402
$\frac{1}{8}$	5.890	0.2761		16.88	22.690		35.73	101.62
$\frac{3}{16}$	7.854	0.4908	$\frac{1}{2}$	17.27	23.758	$\frac{1}{2}$	36.12	103.86
$\frac{1}{4}$	9.817	0.7669		17.67	24.850		36.52	106.13
$\frac{5}{16}$	1.178	1.104	$\frac{3}{4}$	18.06	25.967	$\frac{3}{4}$	36.91	108.43
$\frac{3}{8}$	1.374	1.503		18.45	27.108		37.30	110.75
$\frac{1}{2}$	1.570	1.963	6	18.84	28.274	12	37.69	113.09
$\frac{5}{8}$	1.767	2.485		19.24	29.464		38.09	115.46
$\frac{3}{4}$	1.963	3.067	$\frac{1}{4}$	19.63	30.679	$\frac{1}{4}$	38.48	117.85
$\frac{7}{8}$	2.159	3.712		20.02	31.919		38.87	120.27
1	2.356	4.417	$\frac{1}{2}$	20.42	33.183	$\frac{1}{2}$	39.27	122.71
$1\frac{1}{8}$	2.552	5.184		20.81	34.471		39.66	125.18
$1\frac{1}{4}$	2.748	6.013	$\frac{3}{4}$	21.20	35.784	$\frac{3}{4}$	40.05	127.67
$1\frac{3}{8}$	2.945	6.902		21.57	37.122		40.44	130.19
2	3.141	7.854	7	21.99	38.484	13	40.84	132.73
$2\frac{1}{8}$	3.534	9.940		22.38	39.871		41.23	135.29
$2\frac{1}{4}$	3.927	1.227	$\frac{1}{4}$	22.77	41.282	$\frac{1}{4}$	41.62	137.88
$2\frac{3}{8}$	4.319	1.484		23.16	42.718		42.01	140.50
$2\frac{1}{2}$	4.712	1.767	$\frac{1}{2}$	23.56	44.178	$\frac{1}{2}$	42.41	143.13
$2\frac{5}{8}$	5.105	2.073		23.95	45.663		42.80	145.80
3	5.497	2.405	$\frac{3}{4}$	24.34	47.173	$\frac{3}{4}$	43.19	148.48
$3\frac{1}{8}$	5.890	2.761		24.74	48.707		43.58	151.20
$3\frac{1}{4}$	6.283	3.141	8	25.13	50.265	14	43.98	153.93
$3\frac{3}{8}$	6.675	3.546		25.52	51.848		44.37	156.69
$3\frac{1}{2}$	7.068	3.976	$\frac{1}{4}$	25.91	53.456	$\frac{1}{4}$	44.76	159.48
$3\frac{5}{8}$	7.461	4.430		26.31	55.088		45.16	162.29
$3\frac{3}{4}$	7.854	4.908	$\frac{1}{2}$	26.70	56.745	$\frac{1}{2}$	45.55	165.13
$4\frac{1}{8}$	8.246	5.411		27.09	58.426		45.94	167.98
$4\frac{1}{4}$	8.639	5.939	$\frac{3}{4}$	27.48	60.132	$\frac{3}{4}$	46.33	170.87
$4\frac{3}{8}$	9.032	6.491		27.88	61.862		46.73	173.78
$4\frac{1}{2}$	9.424	7.068	9	28.27	63.617	15	47.12	176.71
$4\frac{5}{8}$	9.817	7.669		28.66	65.396		47.51	179.67
$4\frac{3}{4}$	10.21	8.295	$\frac{1}{4}$	29.05	67.200	$\frac{1}{4}$	47.90	182.65
$5\frac{1}{8}$	10.60	8.946		29.45	69.029		48.30	185.66
$5\frac{1}{4}$	10.99	9.621	$\frac{1}{2}$	29.84	70.882	$\frac{1}{2}$	48.69	188.69
$5\frac{3}{8}$	11.38	10.320		30.23	72.759		49.08	191.74
$5\frac{1}{2}$	11.78	11.044	$\frac{3}{4}$	30.63	74.662	$\frac{3}{4}$	49.48	194.82
$5\frac{5}{8}$	12.17	11.793		31.02	76.588		49.87	197.93
$5\frac{3}{4}$	12.56	12.566	10	31.41	78.539	16	50.26	201.06
$6\frac{1}{8}$	12.95	13.364		31.80	80.515		50.65	204.21
$6\frac{1}{4}$	13.35	14.186	$\frac{1}{4}$	32.20	82.516	$\frac{1}{4}$	51.05	207.39
$6\frac{3}{8}$	13.74	15.033		32.59	84.540		51.44	210.59
$6\frac{1}{2}$	14.13	15.904	$\frac{1}{2}$	32.98	86.590	$\frac{1}{2}$	51.83	213.82
$6\frac{5}{8}$	14.52	16.800		33.37	88.664		52.22	217.07
$6\frac{3}{4}$	14.92	17.720	$\frac{3}{4}$	33.77	90.762	$\frac{3}{4}$	52.62	220.35
$7\frac{1}{8}$	15.31	18.665		34.16	92.885		53.01	223.65

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circ.	Area.	Diameter.	Circ.	Area.	Diameter.	Circ.	Area.
17	53.40	226.98	23	72.25	415.47	29	91.10	660.52
	53.79	230.33		72.64	420.00		91.49	666.22
$\frac{1}{2}$	54.19	233.70	$\frac{1}{2}$	73.04	424.55	$\frac{1}{2}$	91.89	671.95
	54.58	237.10		73.43	429.13		92.28	677.71
$\frac{1}{2}$	54.97	240.52	$\frac{1}{2}$	73.82	433.73	$\frac{1}{2}$	92.67	683.49
	55.37	243.97		74.21	438.30		93.06	689.29
$\frac{3}{4}$	55.76	247.45	$\frac{3}{4}$	74.61	443.01	$\frac{3}{4}$	93.46	695.12
	56.16	250.94		75.00	447.69		93.85	700.98
18	56.54	254.46	24	75.39	452.39	30	94.24	706.86
	56.94	258.01		75.79	457.11		94.64	712.76
$\frac{1}{2}$	57.33	261.58	$\frac{1}{2}$	76.18	461.86	$\frac{1}{2}$	95.03	718.69
	57.72	265.18		76.57	466.63		95.42	724.64
$\frac{1}{2}$	58.11	268.80	$\frac{1}{2}$	76.96	471.43	$\frac{1}{2}$	95.81	730.61
	58.51	272.44		77.36	476.25		96.21	736.61
$\frac{3}{4}$	58.90	276.11	$\frac{3}{4}$	77.75	481.10	$\frac{3}{4}$	96.60	742.64
	59.29	279.81		78.14	485.97		96.99	748.69
19	59.69	283.52	25	78.54	490.87	31	97.38	754.76
	60.08	287.27		78.93	495.79		97.78	760.86
$\frac{1}{2}$	60.47	291.03	$\frac{1}{2}$	79.32	500.74	$\frac{1}{2}$	98.17	766.99
	60.86	294.83		79.71	505.71		98.56	773.14
$\frac{1}{2}$	61.26	298.64	$\frac{1}{2}$	80.10	510.70	$\frac{1}{2}$	98.96	779.31
	61.65	302.48		80.50	515.72		99.35	785.51
$\frac{3}{4}$	62.04	306.35	$\frac{3}{4}$	80.89	520.70	$\frac{3}{4}$	99.74	791.73
	62.43	310.24		81.28	525.83		100.1	797.97
20	62.83	314.16	26	81.68	530.93	32	100.5	804.24
	63.22	318.09		82.07	536.04		100.9	810.54
$\frac{1}{2}$	63.61	322.06	$\frac{1}{2}$	82.46	541.18	$\frac{1}{2}$	101.3	816.86
	64.01	326.05		82.85	546.35		101.7	823.21
$\frac{1}{2}$	64.40	330.06	$\frac{1}{2}$	83.25	551.54	$\frac{1}{2}$	102.1	829.57
	64.79	334.10		83.64	556.76		102.4	835.97
$\frac{3}{4}$	65.18	338.16	$\frac{3}{4}$	84.03	562.00	$\frac{3}{4}$	102.8	842.39
	65.58	342.25		84.43	567.26		103.2	848.83
21	65.97	346.36	27	84.82	572.55	33	103.6	855.30
	66.36	350.49		85.21	577.87		104.0	861.79
$\frac{1}{2}$	66.75	354.65	$\frac{1}{2}$	85.60	583.20	$\frac{1}{2}$	104.4	868.30
	67.15	358.84		86.00	588.57		104.8	874.84
$\frac{1}{2}$	67.54	363.05	$\frac{1}{2}$	86.39	593.95	$\frac{1}{2}$	105.2	881.41
	67.93	367.28		86.78	599.37		105.6	888.00
$\frac{3}{4}$	68.32	371.54	$\frac{3}{4}$	87.17	604.80	$\frac{3}{4}$	106.0	894.61
	68.72	375.82		87.57	610.26		106.4	901.25
22	69.11	380.13	28	87.96	615.75	34	106.8	907.92
	69.50	384.46		88.35	621.26		107.2	914.61
$\frac{1}{2}$	69.90	388.82	$\frac{1}{2}$	88.75	626.79	$\frac{1}{2}$	107.5	921.32
	70.29	393.20		89.14	632.35		107.9	928.06
$\frac{1}{2}$	70.68	397.60	$\frac{1}{2}$	89.53	637.94	$\frac{1}{2}$	108.3	934.82
	71.07	402.03		89.92	643.54		108.7	941.60
$\frac{3}{4}$	71.47	406.49	$\frac{3}{4}$	90.32	649.18	$\frac{3}{4}$	109.1	948.41
	71.86	410.97		90.71	654.83		109.5	955.25

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circ.	Area.	Diameter.	Circ.	Area.	Diameter.	Circ.	Area.
								
35	109.9	962.11	41	128.8	1320.2	47	147.6	1734.9
	110.3	968.99		129.1	1328.3		148.	1744.1
$\frac{1}{4}$	110.7	975.90	$\frac{1}{4}$	129.5	1336.4	$\frac{1}{4}$	148.4	1753.4
	111.1	982.84		129.9	1344.5		148.8	1762.7
$\frac{1}{2}$	111.5	989.80	$\frac{1}{2}$	130.3	1352.6	$\frac{1}{2}$	149.2	1772.0
	111.9	996.78		130.7	1360.8		149.6	1781.3
$\frac{3}{4}$	112.3	1003.7	$\frac{3}{4}$	131.1	1369.0	$\frac{3}{4}$	150.	1790.7
	112.7	1010.8		131.5	1377.2		150.4	1800.1
36	113.	1017.8	42	131.9	1385.4	48	150.7	1809.5
	113.4	1024.9		132.3	1393.7		150.1	1818.9
$\frac{1}{4}$	113.8	1032.0	$\frac{1}{4}$	132.7	1401.9	$\frac{1}{4}$	151.5	1828.4
	114.2	1039.1		133.1	1410.2		151.9	1837.9
$\frac{1}{2}$	114.6	1046.3	$\frac{1}{2}$	133.5	1418.6	$\frac{1}{2}$	152.3	1847.4
	115.	1053.5		133.9	1426.9		152.7	1856.9
$\frac{3}{4}$	115.4	1060.7	$\frac{3}{4}$	134.3	1435.3	$\frac{3}{4}$	153.1	1866.5
	115.8	1067.9		134.6	1443.7		153.5	1876.1
37	116.2	1075.2	43	135.	1452.2	49	153.9	1885.7
	116.6	1082.4		135.4	1460.6		154.3	1895.3
$\frac{1}{4}$	117.	1089.7	$\frac{1}{4}$	135.8	1469.1	$\frac{1}{4}$	154.7	1905.0
	117.4	1097.1		136.2	1477.6		155.1	1914.7
$\frac{1}{2}$	117.8	1104.4	$\frac{1}{2}$	136.6	1486.1	$\frac{1}{2}$	155.5	1924.4
	118.2	1111.8		137.	1494.7		155.9	1934.1
$\frac{3}{4}$	118.6	1119.2	$\frac{3}{4}$	137.4	1503.3	$\frac{3}{4}$	156.2	1943.9
	118.9	1126.6		137.8	1511.9		156.6	1953.6
38	119.3	1134.1	44	138.2	1520.5	50	157.	1963.5
	119.7	1141.5		138.6	1529.1		157.4	1973.3
$\frac{1}{4}$	120.1	1149.0	$\frac{1}{4}$	139.	1537.8	$\frac{1}{4}$	157.8	1983.1
	120.5	1156.6		139.4	1546.5		158.2	1993.0
$\frac{1}{2}$	120.9	1164.1	$\frac{1}{2}$	139.8	1555.2	$\frac{1}{2}$	158.6	2002.9
	121.3	1171.7		140.1	1564.0		159.	2012.8
$\frac{3}{4}$	121.7	1179.3	$\frac{3}{4}$	140.5	1572.8	$\frac{3}{4}$	159.4	2022.8
	122.1	1186.9		140.9	1581.6		159.8	2032.8
39	122.5	1194.5	45	141.3	1590.4	51	160.2	2042.8
	122.9	1202.2		141.7	1599.2		160.6	2052.8
$\frac{1}{4}$	123.3	1209.9	$\frac{1}{4}$	142.1	1608.1	$\frac{1}{4}$	161.	2062.9
	123.7	1217.6		142.5	1617.0		161.3	2072.9
$\frac{1}{2}$	124.	1225.4	$\frac{1}{2}$	142.9	1625.9	$\frac{1}{2}$	161.7	2083.0
	124.4	1233.1		143.3	1634.9		162.1	2093.2
$\frac{3}{4}$	124.8	1240.9	$\frac{3}{4}$	143.7	1643.8	$\frac{3}{4}$	162.5	2103.3
	125.2	1248.7		144.1	1652.8		162.9	2113.5
40	125.6	1256.6	46	144.5	1661.9	52	163.3	2123.7
	126.	1264.5		144.9	1670.9		163.7	2133.9
$\frac{1}{4}$	126.4	1272.3	$\frac{1}{4}$	145.2	1680.0	$\frac{1}{4}$	164.1	2144.1
	126.8	1280.3		145.6	1689.1		164.5	2154.4
$\frac{1}{2}$	127.2	1288.2	$\frac{1}{2}$	146.	1698.2	$\frac{1}{2}$	164.9	2164.7
	127.6	1296.2		146.4	1707.3		165.3	2175.0
$\frac{3}{4}$	128.	1304.2	$\frac{3}{4}$	146.8	1716.5	$\frac{3}{4}$	165.7	2185.4
	128.4	1312.2		147.2	1725.7		166.1	2195.7

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circ.	Area.	Diameter.	Circ.	Area.	Diameter.	Circ.	Area.
53	166.5	2206.1	59	185.3	2733.9	65	204.2	3318.3
	166.8	2216.6		185.7	2745.5		204.5	3331.0
$\frac{1}{2}$	167.2	2227.0	$\frac{1}{2}$	186.1	2757.1	$\frac{1}{2}$	204.9	3343.8
	167.6	2237.5		186.5	2768.8		205.3	3356.7
$\frac{1}{2}$	168.	2248.0	$\frac{1}{2}$	186.9	2780.5	$\frac{1}{2}$	205.7	3369.5
	168.4	2258.5		187.3	2792.2		206.1	3382.4
$\frac{3}{4}$	168.8	2269.0	$\frac{3}{4}$	187.7	2803.9	$\frac{3}{4}$	206.5	3395.3
	169.2	2279.6		188.1	2815.6		206.9	3408.2
54	169.6	2290.2	60	188.4	2827.4	66	207.3	3421.2
	170.	2300.8		188.8	2839.2		207.7	3434.1
$\frac{1}{2}$	170.4	2311.4	$\frac{1}{2}$	189.2	2851.0	$\frac{1}{2}$	208.1	3447.1
	170.8	2322.1		189.6	2862.8		208.5	3460.1
$\frac{1}{2}$	171.2	2332.8	$\frac{1}{2}$	190.	2874.7	$\frac{1}{2}$	208.9	3473.2
	171.6	2343.5		190.4	2886.6		209.3	3486.3
$\frac{3}{4}$	172.	2354.2	$\frac{3}{4}$	190.8	2898.5	$\frac{3}{4}$	209.7	3499.3
	172.3	2365.0		191.2	2910.5		210.	3512.5
55	172.7	2375.8	61	191.6	2922.4	67	210.4	3525.6
	173.1	2386.6		192.	2934.4		210.8	3538.8
$\frac{1}{2}$	173.5	2397.4	$\frac{1}{2}$	192.4	2946.4	$\frac{1}{2}$	211.2	3552.0
	173.9	2408.3		192.8	2958.5		211.6	3565.2
$\frac{1}{2}$	174.3	2419.2	$\frac{1}{2}$	193.2	2970.5	$\frac{1}{2}$	212.	3578.4
	174.7	2430.1		193.6	2982.6		212.4	3591.7
$\frac{3}{4}$	175.1	2441.0	$\frac{3}{4}$	193.9	2994.7	$\frac{3}{4}$	212.8	3605.0
	175.5	2452.0		194.3	3006.9		213.2	3618.3
56	175.9	2463.0	62	194.7	3019.0	68	213.6	3631.6
	176.3	2474.0		195.1	3031.2		214.	3645.0
$\frac{1}{2}$	176.7	2485.0	$\frac{1}{2}$	195.5	3043.4	$\frac{1}{2}$	214.4	3658.4
	177.1	2496.1		195.9	3055.7		214.8	3671.8
$\frac{1}{2}$	177.5	2507.1	$\frac{1}{2}$	196.3	3067.9	$\frac{1}{2}$	215.1	3685.2
	177.8	2518.2		196.7	3080.2		215.5	3698.7
$\frac{3}{4}$	178.2	2529.4	$\frac{3}{4}$	197.1	3092.5	$\frac{3}{4}$	215.9	3712.2
	178.6	2540.5		197.5	3104.8		216.3	3725.7
57	179.	2551.7	63	197.9	3117.2	69	216.7	3739.2
	179.4	2562.9		198.3	3129.6		217.1	3752.8
$\frac{1}{2}$	179.8	2574.1	$\frac{1}{2}$	198.7	3142.0	$\frac{1}{2}$	217.5	3766.4
	180.2	2585.4		199.	3154.4		217.9	3780.0
$\frac{1}{2}$	180.6	2596.7	$\frac{1}{2}$	199.4	3166.9	$\frac{1}{2}$	218.3	3793.6
	181.	2608.0		199.8	3179.4		218.7	3807.3
$\frac{3}{4}$	181.4	2619.3	$\frac{3}{4}$	200.2	3191.9	$\frac{3}{4}$	219.1	3821.0
	181.8	2630.7		200.6	3204.4		219.5	3834.7
58	182.2	2642.0	64	201.	3216.9	70	219.9	3848.4
	182.6	2653.4		201.4	3229.5		220.3	3862.2
$\frac{1}{2}$	182.9	2664.9	$\frac{1}{2}$	201.8	3242.1	$\frac{1}{2}$	220.6	3875.9
	183.3	2676.3		202.2	3254.8		221.	3889.8
$\frac{1}{2}$	183.7	2687.8	$\frac{1}{2}$	202.6	3267.4	$\frac{1}{2}$	221.4	3903.6
	184.1	2699.3		203.	3280.1		221.8	3917.4
$\frac{3}{4}$	184.5	2710.8	$\frac{3}{4}$	203.4	3292.8	$\frac{3}{4}$	222.2	3931.3
	184.9	2722.4		203.8	3305.5		222.6	3945.3

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circ.	Area.	Diameter.	Circ.	Area.	Diameter.	Circ.	Area.
71	223·	3959·2	77	241·9	4656·6	83	260·7	5410·6
	223·4	3973·1		242·2	4671·7		261·1	5426·9
$\frac{1}{2}$	223·8	3987·1	$\frac{1}{2}$	242·6	4686·9	$\frac{1}{2}$	261·5	5443·2
	224·2	4001·1		243·	4702·1		261·9	5459·6
$\frac{1}{2}$	224·6	4015·1	$\frac{1}{2}$	243·4	4717·3	$\frac{1}{2}$	262·3	5476·0
	225·	4029·2		243·8	4732·5		262·7	5492·4
$\frac{2}{3}$	225·4	4043·2	$\frac{2}{3}$	244·2	4747·7	$\frac{2}{3}$	263·1	5508·8
	225·8	4067·3		244·6	4763·0		263·5	5525·3
72	226·1	4071·5	78	245·	4778·3	84	263·8	5541·7
	226·5	4085·6		245·4	4793·7		264·2	5558·2
$\frac{1}{2}$	226·9	4099·8	$\frac{1}{2}$	245·8	4809·0	$\frac{1}{2}$	264·6	5574·8
	227·3	4114·0		246·2	4824·4		265·	5591·3
$\frac{1}{2}$	227·7	4128·2	$\frac{1}{2}$	246·6	4839·8	$\frac{1}{2}$	265·4	5607·9
	228·1	4142·5		247·	4855·2		265·8	5624·5
$\frac{2}{3}$	228·5	4156·7	$\frac{2}{3}$	247·4	4870·7	$\frac{2}{3}$	266·2	5641·1
	228·9	4171·0		247·7	4886·1		266·6	5657·8
73	229·3	4185·3	79	248·1	4901·6	85	267·	5674·5
	229·7	4199·7		248·5	4917·2		267·4	5691·2
$\frac{1}{2}$	230·1	4214·1	$\frac{1}{2}$	248·9	4932·7	$\frac{1}{2}$	267·8	5707·9
	230·5	4228·5		249·3	4948·3		268·2	5724·6
$\frac{1}{2}$	230·9	4242·9	$\frac{1}{2}$	249·7	4963·9	$\frac{1}{2}$	268·6	5741·4
	231·3	4257·3		250·1	4979·5		268·9	5758·2
$\frac{2}{3}$	231·6	4271·8	$\frac{2}{3}$	250·5	4995·1	$\frac{2}{3}$	269·3	5775·0
	232·	4286·3		250·9	5010·8		269·7	5791·9
74	232·4	4300·8	80	251·3	5026·5	86	270·1	5808·8
	232·8	4315·3		251·7	5042·2		270·5	5825·7
$\frac{1}{2}$	233·2	4329·9	$\frac{1}{2}$	252·1	5058·0	$\frac{1}{2}$	270·9	5842·6
	233·6	4344·5		252·5	5073·7		271·3	5859·5
$\frac{1}{2}$	234·	4359·1	$\frac{1}{2}$	252·8	5089·5	$\frac{1}{2}$	271·7	5876·5
	234·4	4373·8		253·2	5105·4		272·1	5893·5
$\frac{2}{3}$	234·8	4388·4	$\frac{2}{3}$	253·6	5121·2	$\frac{2}{3}$	272·5	5910·5
	235·2	4403·1		254·	5137·1		272·9	5927·6
75	235·6	4417·8	81	254·4	5153·0	87	273·3	5944·6
	236·	4432·6		254·8	5168·9		273·7	5961·7
$\frac{1}{2}$	236·4	4447·3	$\frac{1}{2}$	255·2	5184·8	$\frac{1}{2}$	274·1	5978·9
	236·7	4462·1		255·6	5200·8		274·4	5996·0
$\frac{1}{2}$	237·1	4476·9	$\frac{1}{2}$	256·	5216·8	$\frac{1}{2}$	274·8	6013·2
	237·5	4491·8		256·4	5232·8		275·2	6030·4
$\frac{2}{3}$	237·9	4506·6	$\frac{2}{3}$	256·8	5248·8	$\frac{2}{3}$	275·6	6047·6
	238·3	4521·5		257·2	5264·9		276·	6064·8
76	238·7	4536·4	82	257·6	5281·0	88	276·4	6082·1
	239·1	4551·4		258·	5297·1		276·8	6099·4
$\frac{1}{2}$	239·5	4566·3	$\frac{1}{2}$	258·3	5313·2	$\frac{1}{2}$	277·2	6116·7
	239·9	4581·3		258·7	5329·4		277·6	6134·0
$\frac{1}{2}$	240·3	4596·3	$\frac{1}{2}$	259·1	5345·6	$\frac{1}{2}$	278·	6151·4
	240·7	4611·3		259·5	5361·8		278·4	6168·8
$\frac{2}{3}$	241·1	4626·4	$\frac{2}{3}$	259·9	5378·0	$\frac{2}{3}$	278·8	6186·2
	241·5	4641·5		260·3	5394·3		279·2	6203·6

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circ.	Area.	Diameter.	Circ.	Area.	Diameter.	Circ.	Area.
								
89	279.6	6221.1	93	292.1	6792.9	97	304.7	7389.8
	279.9	6238.6		292.5	6811.1		305.1	7408.8
$\frac{1}{4}$	280.3	6256.1	$\frac{1}{4}$	292.9	6829.4	$\frac{1}{4}$	305.5	7427.9
	280.7	6273.6		293.3	6847.8		305.9	7447.0
$\frac{1}{2}$	281.1	6291.2	$\frac{1}{2}$	293.7	6866.1	$\frac{1}{2}$	306.3	7466.2
	281.5	6308.8		294.1	6884.5		306.6	7485.3
$\frac{3}{4}$	281.9	6326.4	$\frac{3}{4}$	294.5	6902.9	$\frac{3}{4}$	307.	7504.5
	282.3	6344.0		294.9	6921.3		307.4	7523.7
90	282.7	6361.7	94	295.3	6939.7	98	307.8	7542.9
	283.1	6379.4		295.7	6958.2		308.2	7562.2
$\frac{1}{4}$	283.5	6397.1	$\frac{1}{4}$	296.	6976.7	$\frac{1}{4}$	308.6	7581.5
	283.9	6414.8		296.4	6995.2		309.0	7600.8
$\frac{1}{2}$	284.3	6432.6	$\frac{1}{2}$	296.8	7013.8	$\frac{1}{2}$	309.4	7620.1
	284.7	6450.4		297.2	7032.3		309.8	7639.4
$\frac{3}{4}$	285.1	6468.2	$\frac{3}{4}$	297.6	7050.9	$\frac{3}{4}$	310.2	7658.8
	285.4	6486.0		298.	7069.5		310.6	7678.2
91	285.8	6503.8	95	298.4	7088.2	99	311.0	7697.7
	286.2	6521.7		298.8	7106.9		311.4	7717.1
$\frac{1}{4}$	286.6	6539.6	$\frac{1}{4}$	299.2	7125.5	$\frac{1}{4}$	311.8	7736.6
	287.	6557.6		299.6	7144.3		312.1	7756.1
$\frac{1}{2}$	287.4	6575.5	$\frac{1}{2}$	300.	7163.0	$\frac{1}{2}$	312.5	7775.6
	287.8	6593.5		300.4	7181.8		312.9	7795.2
$\frac{3}{4}$	288.2	6611.5	$\frac{3}{4}$	300.8	7200.5	$\frac{3}{4}$	313.3	7814.7
	288.6	6629.5		301.2	7219.4		313.7	7834.3
92	289.	6647.6	96	301.5	7238.2	100	314.1	7853.9
	289.4	6665.7		301.9	7257.1		314.5	7873.6
$\frac{1}{4}$	289.8	6683.8	$\frac{1}{4}$	302.3	7275.9	$\frac{1}{4}$	314.9	7893.3
	290.2	6701.9		302.7	7294.9		315.3	7913.1
$\frac{1}{2}$	290.5	6720.0	$\frac{1}{2}$	303.1	7313.8	$\frac{1}{2}$	315.7	7932.7
	290.9	6738.2		303.5	7332.8		316.0	7952.4
$\frac{3}{4}$	291.3	6756.4	$\frac{3}{4}$	303.9	7351.7	$\frac{3}{4}$	316.4	7972.2
	291.7	6776.4		304.3	7370.7		316.8	7991.9

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	$\sqrt{\text{Roots.}}$	$\sqrt[3]{\text{Roots.}}$	Reciprocals.
1	1	1	1.0000000	1.0000000	1.0000000
2	4	8	1.4142136	1.2599210	.500000000
3	9	27	1.7320508	1.4422496	.333333333
4	16	64	2.0000000	1.5874011	.250000000
5	25	125	2.2360680	1.7099759	.200000000
6	36	216	2.4494897	1.8171206	.166666667
7	49	343	2.6457513	1.9129312	.142857143
8	64	512	2.8284271	2.0000000	.125000000
9	81	729	3.0000000	2.0800837	.111111111
10	100	1000	3.1622777	2.1544347	.100000000
11	121	1331	3.3166248	2.2239801	.090909091
12	144	1728	3.4641016	2.2894286	.083333333
13	169	2197	3.6055513	2.3513347	.076923077
14	196	2744	3.7416574	2.4101422	.071428571
15	225	3375	3.8729833	2.4662121	.066666667
16	256	4096	4.0000000	2.5198421	.062500000
17	289	4913	4.1231056	2.5712816	.058823529
18	324	5832	4.2426407	2.6207414	.055555556
19	361	6859	4.3588989	2.6684016	.052631579
20	400	8000	4.4721360	2.7144177	.050000000
21	441	9261	4.5825757	2.7589243	.047619048
22	484	10648	4.6904158	2.8020393	.045454545
23	529	12167	4.7958315	2.8438670	.043478261
24	576	13824	4.8989795	2.8844991	.041666667
25	625	15625	5.0000000	2.9240177	.040000000
26	676	17576	5.0990195	2.9624960	.038461538
27	729	19683	5.1961524	3.0000000	.037037037
28	784	21952	5.2915026	3.0365889	.035714286
29	841	24389	5.3851648	3.0723168	.034482759
30	900	27000	5.4772256	3.1072325	.033333333
31	961	29791	5.5677644	3.1413806	.032258065
32	1024	32768	5.6568542	3.1748021	.031250000
33	1089	35937	5.7445626	3.2075343	.030303030
34	1156	39304	5.8309519	3.2396118	.029411765
35	1225	42875	5.9160798	3.2710663	.028571429
36	1296	46656	6.0000000	3.3019272	.027777778
37	1369	50653	6.0827625	3.3322218	.027027027
38	1444	54872	6.1644140	3.3619754	.026315789
39	1521	59319	6.2449980	3.3912114	.025641026
40	1600	64000	6.3245553	3.4199519	.025000000
41	1681	68921	6.4031242	3.4482172	.024390244
42	1764	74088	6.4807407	3.4760266	.023809524
43	1849	79507	6.5574385	3.5033981	.023255814
44	1936	85184	6.6332496	3.5303483	.022727273
45	2025	91125	6.7082039	3.5568933	.022222222
46	2116	97336	6.7823300	3.5830479	.021739130
47	2209	103823	6.8556546	3.6088261	.021276600
48	2304	110592	6.9282032	3.6342411	.020833333
49	2401	117649	7.0000000	3.6593057	.020408163
50	2500	125000	7.0710678	3.6840314	.020000000
51	2601	132651	7.1414284	3.7084298	.019607843
52	2704	140608	7.2111026	3.7325111	.019230769

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	∛ Roots.	Reciprocals.
53	2809	148877	7·2801099	3·7562858	·018867925
54	2916	157464	7·3484692	3·7797631	·018518519
55	3025	166375	7·4161985	3·8029525	·018181818
56	3136	175616	7·4833148	3·8258624	·017857143
57	3249	185193	7·5498344	3·8485011	·017543860
58	3364	195112	7·6157731	3·8708766	·017241379
59	3481	205379	7·6811457	3·8929965	·016949153
60	3600	216000	7·7459667	3·9148676	·016666667
61	3721	226981	7·8102497	3·9304972	·016393443
62	3844	238328	7·8740079	3·9578915	·016129032
63	3969	250047	7·9372539	3·9790571	·015873016
64	4096	262144	8·0000000	4·0000000	·015625000
65	4225	274625	8·0622577	4·0207256	·015384615
66	4356	287496	8·1240384	4·0412401	·015151515
67	4489	300763	8·1858528	4·0615480	·014925373
68	4624	314432	8·2462113	4·0816551	·014705882
69	4761	328509	8·3066239	4·1015661	·014492754
70	4900	343000	8·3666003	4·1212853	·014285714
71	5041	357911	8·4261498	4·1408178	·014084517
72	5184	373248	8·4852814	4·1601676	·013888889
73	5329	389017	8·5440037	4·1793390	·013698630
74	5476	405224	8·6023253	4·1983364	·013513514
75	5625	421875	8·6602540	4·2171633	·013333333
76	5776	438976	8·7177979	4·2358236	·013157895
77	5929	456533	8·7749644	4·2543210	·012987013
78	6084	474552	8·8317609	4·2726586	·012820513
79	6241	493039	8·8881944	4·2908404	·012658228
80	6400	512000	8·9442719	4·3088695	·012500000
81	6561	531441	9·0000000	4·3267487	·012345679
82	6724	551368	9·0553851	4·3444815	·012195122
83	6889	571787	9·1104336	4·3620707	·012048193
84	7056	592704	9·1651514	4·3795191	·011904762
85	7225	614125	9·2195445	4·3968296	·011764706
86	7396	636056	9·2736185	4·4140049	·011627907
87	7569	658503	9·3273791	4·4310476	·011494253
88	7744	681472	9·3808315	4·4479692	·011363636
89	7921	704969	9·4339811	4·4647451	·011235955
90	8100	729000	9·4868330	4·4814047	·011111111
91	8281	753571	9·5393920	4·4979414	·010989011
92	8464	778688	9·5916630	4·5143574	·010869565
93	8649	804357	9·6436508	4·5306549	·010752688
94	8836	830584	9·6953597	4·5468359	·010638298
95	9025	857375	9·7467943	4·5629026	·010526316
96	9216	884736	9·7979590	4·5788570	·010416667
97	9409	912673	9·8488578	4·5947009	·010309278
98	9604	941192	9·8994949	4·6104363	·010204082
99	9801	970299	9·9498744	4·6260650	·010101010
100	10000	1000000	10·0000000	4·6415888	·010000000
101	10201	1030301	10·0498756	4·6570095	·009900990
102	10404	1061208	10·0995049	4·6723287	·009803922
103	10609	1092727	10·1488916	4·6875482	·009708738
104	10816	1124864	10·1980390	4·7023694	·009615385

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	$\sqrt{\text{Roots.}}$	$\sqrt[3]{\text{Roots.}}$	Reciprocal.
105	11025	1157625	10.2469508	4.7176940	.009523810
106	11236	1191016	10.2956301	4.7326235	.009433962
107	11449	1225043	10.3440804	4.7474594	.009345794
108	11664	1259712	10.3923048	4.7622032	.009259259
109	11881	1295029	10.4403065	4.7768562	.009174312
110	12100	1331000	10.4880885	4.7914199	.009090909
111	12321	1367631	10.5356538	4.8058995	.009009009
112	12544	1404928	10.5830052	4.8202845	.008928571
113	12769	1442897	10.6301458	4.8345881	.008849558
114	12996	1481544	10.6770783	4.8488076	.008771930
115	13225	1520875	10.7238053	4.8629442	.008695652
116	13456	1560896	10.7703296	4.8769990	.008620690
117	13689	1601613	10.8166538	4.8909732	.008547009
118	13924	1643032	10.8627805	4.9048681	.008474576
119	14161	1685159	10.9087121	4.9186847	.008403361
120	14400	1728000	10.9544512	4.9324242	.008333333
121	14641	1771561	11.0000000	4.9460874	.008264463
122	14884	1815848	11.0453610	4.9596757	.008196721
123	15129	1860867	11.0905365	4.9731898	.008130081
124	15376	1906624	11.1355287	4.9866310	.008064516
125	15625	1953125	11.1803399	5.0000000	.008000000
126	15876	2000376	11.2249722	5.0132979	.007936508
127	16129	2048383	11.2694277	5.0265257	.007874016
128	16384	2097152	11.3137085	5.0396842	.007812500
129	16641	2146689	11.3578167	5.0527743	.007751938
130	16900	2197000	11.4017543	5.0657970	.007692308
131	17161	2248091	11.4455231	5.0787531	.007633588
132	17424	2299968	11.4891253	5.0916434	.007575758
133	17689	2352637	11.5325626	5.1044687	.007518797
134	17956	2406104	11.5758369	5.1172299	.007462687
135	18225	2460375	11.6189500	5.1299278	.007407407
136	18496	2515456	11.6619038	5.1425632	.007352941
137	18769	2571353	11.7046999	5.1551387	.007299270
138	19044	2628072	11.7473401	5.1676493	.007246377
139	19321	2685619	11.7898261	5.1801015	.007194245
140	19600	2744000	11.8321596	5.1924941	.007142857
141	19881	2803221	11.8743421	5.2048279	.007092199
142	20164	2863288	11.9163753	5.2171034	.007042254
143	20449	2924207	11.9582607	5.2293215	.006993007
144	20736	2985984	12.0000000	5.2414828	.006944444
145	21025	3048625	12.0415946	5.2535879	.006896552
146	21316	3112136	12.0830460	5.2656374	.006849315
147	21609	3176523	12.1243557	5.2776321	.006802721
148	21904	3241792	12.1655251	5.2895725	.006756757
149	22201	3307949	12.2065556	5.3014592	.006711409
150	22500	3375000	12.2474487	5.3132928	.006666667
151	22801	3442951	12.2882057	5.3250740	.006622517
152	23104	3511008	12.3288280	5.3368033	.006578947
153	23409	3581577	12.3693169	5.3484812	.006535948
154	23716	3652264	12.4096736	5.3601084	.006493506
155	24025	3723875	12.4498996	5.3716854	.006451613
156	24336	3796416	12.4899960	5.3832126	.006410246

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	∛ Roots.	Reciprocals.
157	24649	3869893	12·5299641	5·3946907	·006369427
158	24964	3944312	12·5698051	5·4061202	·006329114
159	25281	4019679	12·6095202	5·4175015	·006289308
160	25600	4096000	12·6491106	5·4288352	·006250000
161	25921	4173281	12·6885775	5·4401218	·006211180
162	26244	4251528	12·7279221	5·4513618	·006172840
163	26569	4330747	12·7671453	5·4625556	·006134969
164	26896	4410944	12·8062485	5·4737037	·006097561
165	27225	4492125	12·8452326	5·4848066	·006060606
166	27556	4574296	12·8840987	5·4958647	·006024096
167	27889	4657463	12·9228480	5·5068784	·005988024
168	28224	4741632	12·9614814	5·5178484	·005952381
169	28561	4826809	13·0000000	5·5287748	·005917160
170	28900	4913000	13·0384048	5·5396583	·005882353
171	29241	5000211	13·0766968	5·5504991	·005847953
172	29584	5088448	13·1148770	5·5612978	·005813953
173	29929	5177717	13·1529464	5·5720546	·005780347
174	30276	5268024	13·1909060	5·5827702	·005747126
175	30625	5359375	13·2287566	5·5934447	·005714286
176	30976	5451776	13·2664992	5·6040787	·005681818
177	31329	5545233	13·3041347	5·6146724	·005649713
178	31684	5639752	13·3416641	5·6252263	·005617973
179	32041	5735339	13·3790882	5·6357408	·005586592
180	32400	5832000	13·4164079	5·6462162	·005555556
181	32761	5929741	13·4536240	5·6566528	·005524862
182	33124	6028568	13·4907376	5·6670511	·005494505
183	33489	6128487	13·5277493	5·6774114	·005464481
184	33856	6229504	13·5646600	5·6877340	·005434783
185	34225	6331625	13·6014705	5·6980192	·005405405
186	34596	6434856	13·6381817	5·7082675	·005376344
187	34969	6539203	13·6747943	5·7184791	·005347594
188	35344	6644672	13·7113092	5·7286543	·005319149
189	35721	6751269	13·7477271	5·7387936	·005291005
190	36100	6859000	13·7840488	5·7488971	·005263158
191	36481	6967871	13·8202750	5·7589652	·005235602
192	36864	7077888	13·8564065	5·7689982	·005208333
193	37249	7189517	13·8924400	5·7789966	·005181347
194	37636	7301384	13·9283883	5·7889604	·005154639
195	38025	7414875	13·9642400	5·7988900	·005128205
196	38416	7529536	14·0000000	5·8087857	·005102041
197	38809	7645373	14·0356688	5·8186479	·005076142
198	39204	7762392	14·0712473	5·8284867	·005050505
199	39601	7880599	14·1067360	5·8382725	·005025126
200	40000	8000000	14·1421356	5·8480355	·005000000
201	40401	8120601	14·1774469	5·8577660	·004975124
202	40804	8242408	14·2126704	5·8674673	·004950495
203	41209	8365427	14·2478068	5·8771307	·004926108
204	41616	8489664	14·2828569	5·8867653	·004901961
205	42025	8615125	14·3178211	5·8963685	·004878049
206	42436	8741816	14·3527001	5·9059406	·004854369
207	42849	8869743	14·3874946	5·9154817	·004830918
208	43264	8998912	14·4222051	5·9249921	·004807697

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares	Cubes.	√ Roots.	³ √ Roots.	Reciprocals.
209	43681	9129329	14·4568323	5·9344721	·004784689
210	44100	9261000	14·4913767	5·9439220	·004761905
211	44521	9393931	14·5258390	5·9533418	·004739336
212	44944	9528128	14·5602198	5·9627320	·004716981
213	45369	9663597	14·5945195	5·9720926	·004694836
214	45796	9800344	14·6287388	5·9814240	·004672897
215	46225	9938375	14·6628783	5·9907264	·004651163
216	46656	10077696	14·6969385	6·0000000	·004629630
217	47089	10218313	14·7309199	6·0092450	·004608295
218	47524	10360232	14·7648231	6·0184617	·004587156
219	47961	10503459	14·7986486	6·0276502	·004566210
220	48400	10648000	14·8323970	6·0368107	·004545455
221	48841	10793861	14·8660687	6·0459435	·004524887
222	49284	10941048	14·8996644	6·0550489	·004504505
223	49729	11089567	14·9331845	6·0641270	·004484305
224	50176	11239424	14·9666295	6·0731779	·004464286
225	50625	11390625	15·0000000	6·0824020	·004444444
226	51076	11543176	15·0332964	6·0991994	·004424779
227	51529	11697083	15·0665192	6·1001702	·004405286
228	51984	11852352	15·0996689	6·1091147	·004385965
229	52441	12008989	15·1327460	6·1180332	·004366812
230	52900	12167000	15·1657509	6·1269257	·004347826
231	53361	12326391	15·1986842	6·1357924	·004329004
232	53824	12487168	15·2315462	6·1446337	·004310345
233	54289	12649337	15·2643375	6·1534495	·004291845
234	54756	12812904	15·2970585	6·1622401	·004273504
235	55225	12977875	15·3297097	6·1710058	·004255319
236	55696	13144256	15·3622915	6·1797466	·004237288
237	56169	13312053	15·3948043	6·1884628	·004219409
238	56644	13481272	15·4272486	6·1971544	·004201681
239	57121	13651919	15·4596248	6·2058218	·004184100
240	57600	13824000	15·4919334	6·2144650	·004166667
241	58081	13997521	15·5241747	6·2230843	·004149378
242	58564	14172488	15·5563492	6·2316797	·004132231
243	59049	14348907	15·5884573	6·2402515	·004115226
244	59536	14526784	15·6204994	6·2487998	·004098361
245	60025	14706125	15·6524758	6·2573248	·004081633
246	60516	14886936	15·6843871	6·2658266	·004065041
247	61009	15069223	15·7162336	6·2743054	·004048583
248	61504	15252992	15·7480157	6·2827613	·004032258
249	62001	15438249	15·7797338	6·2911946	·004016064
250	62500	15625000	15·8113883	6·2996056	·004000000
251	63001	15813251	15·8429795	6·3079935	·003984064
252	63504	16003008	15·8745079	6·3163596	·003968254
253	64009	16194277	15·9059737	6·3247035	·003952569
254	64516	16387064	15·9373775	6·3330256	·003937008
255	65025	16581375	15·9687194	6·3413257	·003921569
256	65536	16777216	16·0000000	6·3496042	·003906250
257	66049	16974593	16·0312195	6·3578611	·003891051
258	66564	17173512	16·0623784	6·3660968	·003875969
259	67081	17373979	16·0934769	6·3743111	·003861004
260	67600	17576000	16·1245155	6·3825043	·003846164

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	√ Roots.	Reciprocals.
261	68121	17779581	16-1554944	6-3906765	·003831418
262	68644	17984728	16-1864141	6-3988279	·003816794
263	69169	18191447	16-2172747	6-4069585	·003802281
264	69696	18399744	16-2480768	6-4150687	·003787879
265	70225	18609625	16-2788206	6-4231583	·003773585
266	70756	18821096	16-3095064	6-4312276	·003759398
267	71289	19034163	16-3401346	6-4392767	·003745318
268	71824	19248832	16-3707055	6-4473057	·003731343
269	72361	19465109	16-4012195	6-4553148	·003717472
270	72900	196833000	16-4316767	6-4633041	·003703704
271	73441	19902511	16-4620776	6-4712736	·003690037
272	73984	20123643	16-4924225	6-4792236	·003676471
273	74529	20346417	16-5227116	6-4871541	·003663004
274	75076	20570824	16-5529454	6-4950653	·003649635
275	75625	20796875	16-5831240	6-5029572	·003636364
276	76176	21024576	16-6132477	6-5108300	·003623188
277	76729	21263933	16-6433170	6-5186839	·003610108
278	77284	21484952	16-6783320	6-5265189	·003597122
279	77841	21717639	16-7032931	6-5343351	·003584229
280	78400	21952000	16-7332005	6-5421326	·003571429
281	78961	22188041	16-7630546	6-5499116	·003558719
282	79524	22425768	16-7928556	6-5576722	·003546099
283	80089	22665187	16-8226038	6-5654144	·003533569
284	80656	22906304	16-8522995	6-5731385	·003521127
285	81225	23149125	16-8819430	6-5808443	·003508772
286	81796	23393656	16-9115345	6-5885323	·003496503
287	82369	23639903	16-9410743	6-5962023	·003484321
288	82944	23887872	16-9705627	6-6038545	·003472222
289	83521	24137569	17-0000000	6-6114890	·003460208
290	84100	24389000	17-0293864	6-6191060	·003448276
291	84681	24642171	17-0587221	6-6267054	·003436426
292	85264	24897088	17-0880075	6-6342874	·003424658
293	85849	25153757	17-1172428	6-6418522	·003412969
294	86436	25412184	17-1464282	6-6493998	·003401361
295	87025	25672375	17-1755640	6-6569302	·003389831
296	87616	25934836	17-2046505	6-6644437	·003378378
297	88209	26198073	17-2336879	6-6719403	·003367003
298	88804	26463592	17-2626765	6-6794200	·003355705
299	89401	26730899	17-2916165	6-6868831	·003344482
300	90000	27000000	17-3205081	6-6943295	·003333333
301	90601	27270901	17-3493516	6-7017593	·003322259
302	91204	27543608	17-3781472	6-7091729	·003311258
303	91809	27818127	17-4068952	6-7165700	·003301330
304	92416	28094464	17-4355958	6-7239508	·003289474
305	93025	28372625	17-4642492	6-7313155	·003278689
306	93636	28652616	17-4928557	6-7386641	·003267974
307	94249	28934443	17-5214155	6-7459967	·003257329
308	94864	29218112	17-5499288	6-7533134	·003246753
309	95481	29503609	17-5783958	6-7606143	·003236246
310	96100	29791000	17-6068169	6-7678995	·003225806
311	96721	30080231	17-6351921	6-7751690	·003215434
312	97344	30371328	17-6635217	6-7824229	·003205128

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	³ √ Roots.	Reciprocals.
313	97966	30664297	17.6918060	6.7896613	·003194888
314	98596	30959144	17.7200451	6.7968844	·003184713
315	99225	31255875	17.7482393	6.8040921	·003174603
316	99856	31554496	17.7763888	6.8112847	·003164557
317	100489	31855013	17.8044938	6.8184620	·003154574
318	101124	32157432	17.8325545	6.8256242	·003144654
319	101761	32461759	17.8605711	6.8327714	·003134796
320	102400	32768000	17.8885438	6.8399037	·003125000
321	103041	33076161	17.9164729	6.8470213	·003115265
322	103684	33386248	17.9443584	6.8541240	·003105590
323	104329	33698267	17.9722008	6.8612120	·003095975
324	104976	34012224	18.0000000	6.8682855	·003086420
325	105625	34328125	18.0277564	6.8753433	·003076923
326	106276	34645976	18.0554701	6.8823888	·003067485
327	106929	34965783	18.0831413	6.8894188	·003048104
328	107584	35287552	18.1107703	6.8964345	·003048780
329	108241	35611289	18.1383571	6.9034359	·003039514
330	108900	35937000	18.1659021	6.9104232	·003030303
331	109561	36264691	18.1934054	6.9173964	·003021148
332	110224	36594368	18.2208672	6.9243556	·003012048
333	110889	36926037	18.2482876	6.9313088	·003003003
334	111556	37259704	18.2756669	6.9382321	·002994012
335	112225	37595375	18.3030052	6.9451496	·002985075
336	112896	37933056	18.3303028	6.9520533	·002976190
337	113569	38272753	18.3575598	6.9589434	·002967359
338	114244	38614472	18.3847763	6.9658198	·002958580
339	114921	38958219	18.4119526	6.9726826	·002949853
340	115600	39304000	18.4390889	6.9795321	·002941176
341	116281	39651821	18.4661853	6.9863681	·002932551
342	116964	40001688	18.4932420	6.9931906	·002923977
343	117649	40353607	18.5202592	7.0000000	·002915452
344	118336	40707584	18.5472370	7.0067962	·002906977
345	119025	41063625	18.5741756	7.0135791	·002898551
346	119716	41421736	18.6010752	7.0203490	·002890173
347	120409	41781923	18.6279360	7.0271058	·002881844
348	121104	42144192	18.6547581	7.0338497	·002873563
349	121801	42508549	18.6815417	7.0405860	·002865330
350	122500	42875000	18.7082869	7.0472987	·002857143
351	123201	43243551	18.7349940	7.0540041	·002849003
352	123904	43614208	18.7616630	7.0606967	·002840909
353	124609	43986977	18.7882942	7.0673767	·002832861
354	125316	44361864	18.8148877	7.0740440	·002824859
355	126025	44738875	18.8414437	7.0806988	·002816901
356	126736	45118016	18.8679623	7.0873411	·002808989
357	127449	45499293	18.8944436	7.0939709	·002801120
358	128164	45882712	18.9208879	7.1005885	·002793296
359	128881	46268279	18.9472953	7.1071937	·002785515
360	129600	46656000	18.9736660	7.1137866	·002777778
361	130321	47045831	19.0000000	7.1203674	·002770083
362	131044	47437928	19.0262976	7.1269360	·002762431
363	131769	47832147	19.0525589	7.1334925	·002754821
364	132496	48228544	19.0787840	7.1400370	·002747253

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	√ Roots.	Reciprocals.
365	133225	48627125	19.1049732	7.1465695	0.02739726
366	133956	49027896	19.1311265	7.1530901	0.02732240
367	134689	49430863	19.1572441	7.1595988	0.02724796
368	135424	49836032	19.1833261	7.1660957	0.02717391
369	136161	50243409	19.2093727	7.1725809	0.02710027
370	136900	50653000	19.2353841	7.1790544	0.02702703
371	137641	51064811	19.2613603	7.1855162	0.02695418
372	138384	51478848	19.2873015	7.1919663	0.02688172
373	139129	51895117	19.3132079	7.1984050	0.02680965
374	139876	52313624	19.3390796	7.2048322	0.02673797
375	140625	52734375	19.3649167	7.2112479	0.02666667
376	141376	53157376	19.3907194	7.2176522	0.02659574
377	142129	53582633	19.4164878	7.2240450	0.02652520
378	142884	54010152	19.4422221	7.2304268	0.02645503
379	143641	54439939	19.4679223	7.2367972	0.02638521
380	144400	54872000	19.4935887	7.2431565	0.02631579
381	145161	55306341	19.5192213	7.2495045	0.02624672
382	145924	55742968	19.5448203	7.2558415	0.02617801
383	146689	56181887	19.5703858	7.2621675	0.02610966
384	147456	56623104	19.5959179	7.2684824	0.02604167
385	148225	57066625	19.6214169	7.2747864	0.02597403
386	148996	57512456	19.6468827	7.2810794	0.02590674
387	149769	57960603	19.6723156	7.2873617	0.02583979
388	150544	58411072	19.6977156	7.2936330	0.02577320
389	151321	58863869	19.7230829	7.2998936	0.02570694
390	152100	59319000	19.7484177	7.3061436	0.02564103
391	152881	59776471	19.7737199	7.3123828	0.02557545
392	153664	60236288	19.7989899	7.3186114	0.02551020
393	154449	60698457	19.8242276	7.3248295	0.02544529
394	155236	61162984	19.8494332	7.3310369	0.02538071
395	156025	61629875	19.8746069	7.3372339	0.02531646
396	156816	62099136	19.8997487	7.3434205	0.02525253
397	157609	62570773	19.9248588	7.3495966	0.02518892
398	158404	63044792	19.9499373	7.3557624	0.02512563
399	159201	63521199	19.9749844	7.3619178	0.02506266
400	160000	64000000	20.0000000	7.3680630	0.02500000
401	160801	64481201	20.0249844	7.3741979	0.02493766
402	161604	64964808	20.0499377	7.3803227	0.02487562
403	162409	65450827	20.0748599	7.3864373	0.02481390
404	163216	65939264	20.0997512	7.3925418	0.02475248
405	164025	66430125	20.1246118	7.3986363	0.02469136
406	164836	66923416	20.1494417	7.4047206	0.02463054
407	165649	67419143	20.1742410	7.4107950	0.02456902
408	166464	67917312	20.1990099	7.4168595	0.02450788
409	167281	68417929	20.2237484	7.4229142	0.02444698
410	168100	68921000	20.2484567	7.4289589	0.02438624
411	168921	69426531	20.2731349	7.4349938	0.02432569
412	169744	69934528	20.2977831	7.4410189	0.02426534
413	170569	70444997	20.3224014	7.4470343	0.02420518
414	171396	70957944	20.3469899	7.4530399	0.02414529
415	172225	71473375	20.3715488	7.4590359	0.02408563
416	173056	71991296	20.3960781	7.4650223	0.02402616

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares	Cubes.	$\sqrt{\text{Roots.}}$	$\sqrt[3]{\text{Roots.}}$	Reciprocals.
417	173889	72511713	20·4205779	7·4709991	·002398082
418	174724	73034632	20·4450483	7·4769664	·002392344
419	175561	73560059	20·4694895	7·4829242	·002386635
420	176400	74088000	20·4939015	7·4888724	·002380952
421	177241	74618461	20·5182845	7·4948113	·002375297
422	178084	75151448	20·5426386	7·5007406	·002369668
423	178929	75686967	20·5669638	7·5066607	·002364066
424	179776	76225024	20·5912603	7·5125715	·002358491
425	180625	76765625	20·6155281	7·5184730	·002352941
426	181476	77308776	20·6397674	7·5243652	·002347418
427	182329	77854483	20·6639783	7·5302482	·002341920
428	183184	78402752	20·6881609	7·5361221	·002336449
429	184041	78953589	20·7123152	7·5419867	·002331002
430	184900	79507000	20·7364414	7·5478423	·002325581
431	185761	80062991	20·7605395	7·5536888	·002320186
432	186624	80621568	20·7846097	7·5595263	·002314815
433	187489	81182737	20·8086520	7·5653548	·002309469
434	188356	81746504	20·8326667	7·5711743	·002304147
435	189225	82312875	20·8566536	7·5769849	·002298851
436	190096	82881856	20·8806130	7·5827865	·002293578
437	190969	83453453	20·9045450	7·5885793	·002288330
438	191844	84027672	20·9284495	7·5943633	·002283105
439	192721	84604519	20·9523268	7·6001385	·002277904
440	193600	85184000	20·9761770	7·6059049	·002272727
441	194481	85766121	21·0000000	7·6116626	·002267574
442	195364	86350888	21·0237960	7·6174116	·002262443
443	196249	86938307	21·0475652	7·6231519	·002257336
444	197136	87528384	21·0713075	7·6288837	·002252252
445	198025	88121125	21·0950231	7·6346067	·002247191
446	198916	88716536	21·1187121	7·6403213	·002242152
447	199809	89314623	21·1423745	7·6460272	·002237136
448	200704	89915392	21·1660105	7·6517247	·002232143
449	201601	90518849	21·1896201	7·6574138	·002227171
450	202500	91125000	21·2132034	7·6630943	·002222222
451	203401	91733851	21·2367606	7·6687665	·002217295
452	204304	92345408	21·2602916	7·6744303	·002212389
453	205209	92959677	21·2837967	7·6800857	·002207506
454	206116	93576664	21·3072758	7·6857328	·002202643
455	207025	94196375	21·3307290	7·6913717	·0021 7802
456	207936	94818816	21·3541565	7·6970023	·002192982
457	208849	95443993	21·3775583	7·7026246	·002188184
458	209764	96071912	21·4009346	7·7082388	·002183406
459	210681	96702579	21·4242853	7·7138448	·002178649
460	211600	97336000	21·4476106	7·7194426	·002173913
461	212521	97972181	21·4709106	7·7250325	·002169197
462	213444	98611128	21·4941853	7·7306141	·002164502
463	214369	99252847	21·5174348	7·7361977	·002159827
464	215296	99897344	21·5406592	7·7417532	·002155172
465	216225	100544625	21·5638587	7·7473109	·002150538
466	217156	101194696	21·5870331	7·7528606	·002145923
467	218089	101847563	21·6101828	7·7584023	·002141328
468	219024	102593232	21·6333077	7·7639361	·002136752

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√Roots.	∛Roots.	Reciprocals.
469	219961	105161709	21·6564078	7·7694620	·002132196
470	220900	103823000	21·6794834	7·7749801	·002127660
471	221841	104487111	21·7025344	7·7804904	·002123142
472	222784	105154048	21·7255610	7·7859928	·002118644
473	223729	105828817	21·7485632	7·7914875	·002114165
474	224676	106496424	21·7715411	7·7969745	·002109705
475	225625	107171875	21·7944947	7·8024538	·002105263
476	226576	107850176	21·8174242	7·8079254	·002100840
477	227529	108531333	21·8403297	7·8133892	·002096436
478	228484	109215352	21·8632111	7·8188456	·002092050
479	229441	109902239	21·8860686	7·8242942	·002087683
480	230400	110592000	21·9089023	7·8297353	·002083333
481	231361	111284641	21·9317122	7·8351688	·002079002
482	232324	111980168	21·9544984	7·8405949	·002074689
483	233289	112678587	21·9772610	7·8460134	·002070393
484	234256	113379904	22·0000000	7·8514244	·002066116
485	235225	114084125	22·0227155	7·8568281	·002061856
486	236196	114791256	22·0454077	7·8622242	·002057613
487	237169	115501303	22·0680765	7·8676130	·002053388
488	238144	116214272	22·0907220	7·8729944	·002049180
489	239121	116930169	22·1133444	7·8783684	·002044990
490	240100	117649000	22·1359436	7·8837352	·002040816
491	241081	118370771	22·1585198	7·8890946	·002036660
492	242064	119095488	22·1810730	7·8944468	·002032520
493	243049	119823157	22·2036033	7·8997917	·002028398
494	244036	120553784	22·2261108	7·9051294	·002024291
495	245025	121287375	22·2485955	7·9104599	·002020202
496	246016	122023936	22·2710575	7·9157832	·002016129
497	247009	122763473	22·2934968	7·9210994	·002012072
498	248004	123505992	22·3159136	7·9264085	·002008032
499	249001	124251499	22·3383079	7·9317104	·002004008
500	250000	125000000	22·3606798	7·9370053	·002000000
501	251001	125751501	22·3830293	7·9422931	·001996008
502	252004	126506008	22·4053565	7·9475739	·001992032
503	253009	127263527	22·4276615	7·9528477	·001988072
504	254016	128024064	22·4499443	7·9581144	·001984127
505	255025	128787625	22·4722051	7·9633743	·001980198
506	256036	129554216	22·4944438	7·9686271	·001976285
507	257049	130323843	22·5166605	7·9738731	·001972387
508	258064	131096512	22·5388553	7·9791122	·001968504
509	259081	131872229	22·5610283	7·9843444	·001964637
510	260100	132651000	22·5831796	7·9895697	·001960784
511	261121	133432831	22·6053091	7·9947883	·001956947
512	262144	134217728	22·6274170	8·0000000	·001953125
513	263169	135005697	22·6495033	8·0052049	·001949318
514	264196	135796744	22·6715681	8·0104032	·001945525
515	265225	136590875	22·6936114	8·0155946	·001941748
516	266256	137388096	22·7156334	8·0207794	·001937984
517	267289	138188413	22·7376341	8·0259574	·001934236
518	268324	138991832	22·7596134	8·0311287	·001930502
519	269361	139798359	22·7815715	8·0362935	·001926782
520	270400	140608000	22·8035085	8·0414516	·001923077

TABLES OF SQUARES, CUBES SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	∛ Roots.	Reciprocals.
521	271441	141420761	22-8254244	8-0466030	·001919386
522	272484	142236648	22-8473193	8-0517479	·001915709
523	273529	143055667	22-8691933	8-0568862	·001912046
524	274576	143877824	22-8910463	8-0620180	·001908397
525	275625	144703125	22-9128785	8-0671432	·001904762
526	276676	145531576	22-9346899	8-0722620	·001901141
527	277729	146363183	22-9564806	8-0773745	·001897533
528	278784	147197952	22-9782506	8-0824800	·001893939
529	279841	148035889	23-0000000	8-0875794	·001890359
530	280900	148877001	23-0217289	8-0926723	·001886792
531	281961	149721291	23-0434372	8-0977589	·001883239
532	283024	150568768	23-0651252	8-1028390	·001879699
533	284089	151419437	23-0867928	8-1079128	·001876173
534	285156	152273304	23-1084400	8-1129803	·001872659
535	286225	153130375	23-1300670	8-1180414	·001869159
536	287296	153990656	23-1516738	8-1230962	·001865672
537	288369	154854153	23-1732605	8-1281447	·001862197
538	289444	155720872	23-1948270	8-1331870	·001858736
539	290521	156590819	23-2163735	8-1382230	·001855288
540	291600	157464000	23-2379001	8-1432529	·001851852
541	292681	158340421	23-2594067	8-1482765	·001848429
542	293764	159220088	23-2808935	8-1532939	·001845018
543	294849	160103007	23-3023604	8-1583051	·001841621
544	295936	160989184	23-3238076	8-1633102	·001838235
545	297025	161878625	23-3452351	8-1683092	·001834862
546	298116	162771336	23-3666429	8-1733020	·001831502
547	299209	163667323	23-3880311	8-1782888	·001828154
548	300304	164566592	23-4093998	8-1832695	·001824818
549	301401	165469149	23-4307490	8-1882441	·001821494
550	302500	166375000	23-4520788	8-1932127	·001818182
551	303601	167284151	23-4733892	8-1981753	·001814892
552	304704	168196608	23-4946802	8-2031319	·001811594
553	305809	169112377	23-5159520	8-2080825	·001808318
554	306916	170031464	23-5372046	8-2130271	·001805054
555	308025	170953875	23-5584380	8-2179657	·001801802
556	309136	171879616	23-5796522	8-2228985	·001798561
557	310249	172808693	23-6008474	8-2278254	·001795332
558	311364	173741112	23-6220236	8-2327463	·001792115
559	312481	174676879	23-6431808	8-2376614	·001788909
560	313600	175616000	23-6643191	8-2425706	·001785714
561	314721	176558481	23-6854386	8-2474740	·001782531
562	315844	177504328	23-7065392	8-2523715	·001779359
563	316969	178453547	23-7276210	8-2572635	·001776199
564	318096	179406144	23-7486842	8-2621492	·001773050
565	319225	180362125	23-7697286	8-2670294	·001769912
566	320356	181321496	23-7907545	8-2719039	·001766784
567	321489	182284263	23-8117618	8-2767726	·001763668
568	322624	183250432	23-8327506	8-2816255	·001760563
569	323761	184220009	23-8537209	8-2864928	·001757469
570	324900	185193000	23-8746728	8-2913444	·001754386
571	326041	186169411	23-8956063	8-2961903	·001751313
572	327184	187149248	23-9165215	8-3010304	·001748252

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	$\sqrt{\text{Roots.}}$	$\sqrt[3]{\text{Roots.}}$	Reciprocals.
573	328329	188132517	23.9374184	8.3058651	•001745201
574	329476	189119224	23.9582971	8.3106941	•001742160
575	330625	190109375	23.9791576	8.3155175	•001739130
576	331776	191102976	24.0000000	8.3203353	•001736111
577	332927	192100033	24.0208243	8.3251475	•001733162
578	334084	193100552	24.0416306	8.3299542	•001730104
579	335241	194104539	24.0624188	8.3347553	•001727116
580	336400	195112000	24.0831891	8.3395509	•001724138
581	337561	196122941	24.1039416	8.3443410	•001721170
582	338724	197137368	24.1246762	8.3491256	•001718213
583	339889	198155287	24.1453929	8.3539047	•001715266
584	341056	199176704	24.1660919	8.3586784	•001712329
585	342225	200201625	24.1867732	8.3634466	•001709402
586	343396	201230056	24.2074369	8.3682095	•001706485
587	344569	202262003	24.2280829	8.3729668	•001703578
588	345744	203297472	24.2487113	8.3777188	•001700680
589	346921	204336469	24.2693222	8.3824653	•001697793
590	348100	205379000	24.2899156	8.3872065	•001694915
591	349281	206425071	24.3104996	8.3919428	•001692047
592	350464	207474688	24.3310501	8.3966729	•001689189
593	351649	208527857	24.3515913	8.4013981	•001686341
594	352836	209584584	24.3721152	8.4061180	•001683502
595	354025	210644875	24.3926218	8.4108326	•001680672
596	355216	211708736	24.4131112	8.4155419	•001677852
597	356409	212776173	24.4335834	8.4202460	•001675042
598	357604	213847192	24.4540385	8.4249448	•001672241
599	358801	214921799	24.4744765	8.4296383	•001669449
600	360000	216000000	24.4948974	8.4343267	•001666667
601	361201	217081801	24.5153013	8.4390098	•001663894
602	362404	218167208	24.5356883	8.4436877	•001661130
603	363609	219256227	24.5560583	8.4483605	•001658375
604	364816	220348864	24.5764115	8.4530281	•001655629
605	366025	221445125	24.5967478	8.4576906	•001652893
606	367236	222545016	24.6170673	8.4623479	•001650165
607	368449	223648543	24.6373700	8.4670001	•001647446
608	369664	224755712	24.6576560	8.4716471	•001644737
609	370881	225866529	24.6779254	8.4762892	•001642036
610	372100	226981000	24.6981781	8.4809261	•001639344
611	373321	228099131	24.7184142	8.4855579	•001636661
612	374544	229220928	24.7386338	8.4901848	•001633987
613	375769	230346397	24.7588368	8.4948065	•001631321
614	376996	231475544	24.7790234	8.4994233	•001628664
615	378225	232608375	24.7991935	8.5040350	•001626016
616	379456	233744896	24.8193473	8.5086417	•001623377
617	380689	234885113	24.8394847	8.5132435	•001620746
618	381924	236029032	24.8596058	8.5178403	•001618123
619	383161	237176659	24.8797106	8.5224331	•001615509
620	384400	238328000	24.8997992	8.5270189	•001612903
621	385641	239483061	24.9198716	8.5316009	•001610306
622	386884	240641848	24.9399278	8.5361780	•001607717
623	388129	241804367	24.9599679	8.5407501	•001605136
624	389376	242970624	24.9799920	8.5453173	001602564

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	∛ Roots.	Reciprocal.
625	390625	244140625	25.0000000	8.5498797	.001600000
626	391876	245134376	25.0199920	8.5544372	.001597444
627	393129	246491883	25.0399681	8.5589899	.001594896
628	394384	247673152	25.0599282	8.5635377	.001592357
629	395641	248858189	25.0798724	8.5680807	.001589825
630	396900	250047000	25.0998008	8.5726189	.001587302
631	398161	251239591	25.1197134	8.5771523	.001584786
632	399424	252435968	25.1396102	8.5816809	.001582278
633	400689	253636137	25.1594913	8.5862247	.001579779
634	401956	254840104	25.1793566	8.5907238	.001577287
635	403225	256047875	25.1992063	8.5952380	.001574803
636	404496	257259456	25.2190404	8.5997476	.001572327
637	405769	258474853	25.2388589	8.6042525	.001569859
638	407044	259694072	25.2586619	8.6087526	.001567398
639	408321	260917119	25.2784493	8.6132480	.001564945
640	409600	262144000	25.2982213	8.6177388	.001562500
641	410881	263374721	25.3179778	8.6222248	.001560062
642	412164	264609288	25.3377189	8.6267063	.001557632
643	413449	265847707	25.3574447	8.6311830	.001555210
644	414736	267089984	25.3771551	8.6356551	.001552795
645	416025	268336125	25.3968502	8.6401226	.001550388
646	417316	269585136	25.4165302	8.6445855	.001547988
647	418609	270840023	25.4361947	8.6490437	.001545595
648	419904	272097792	25.4558441	8.6534974	.001543210
649	421201	273359449	25.4754784	8.6579465	.001540832
650	422500	274625000	25.4950976	8.6623911	.001538462
651	423801	275894451	25.5147013	8.6668310	.001536098
652	425104	277167808	25.5342907	8.6712665	.001533742
653	426409	278445077	25.5538647	8.6756974	.001531394
654	427716	279726264	25.5734237	8.6801237	.001529052
655	429025	281011375	25.5929678	8.6845456	.001526718
656	430336	282300416	25.6124969	8.6889630	.001524390
657	431649	283593393	25.6320112	8.6933759	.001522070
658	432964	284890312	25.6515107	8.6977843	.001519757
659	434281	286191179	25.6709953	8.7021882	.001517451
660	435600	287496000	25.6904652	8.7065877	.001515152
661	436921	288804781	25.7099203	8.7109827	.001512859
662	438244	290117528	25.7293607	8.7153734	.001510574
663	439569	291434247	25.7487864	8.7197596	.001508296
664	440896	292754944	25.7681975	8.7241414	.001506024
665	442225	294079625	25.7875939	8.7285187	.001503759
666	443556	295408296	25.8069758	8.7328918	.001501502
667	444889	296740963	25.8263431	8.7372604	.001499250
668	446224	298077632	25.8456960	8.7416246	.001497006
669	447561	299418309	25.8650343	8.7459846	.001494768
670	448900	300763000	25.8843582	8.7503401	.001492537
671	450241	302111711	25.9036677	8.7546913	.001490313
672	451584	303464448	25.9229628	8.7590383	.001488095
673	452929	304821217	25.9422435	8.7633809	.001485884
674	454276	306182024	25.9615100	8.7677192	.001483680
675	455625	307546875	25.9807621	8.7720532	.001481481
676	456976	308915776	26.0000000	8.7763830	.001479290

TABLES OF SQUARES, CUBES SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	$\sqrt{\quad}$ Roots.	$\sqrt[3]{\quad}$ Roots.	Reciprocals.
677	458329	310288733	26.0192237	8.7807084	.001477105
678	459684	311665752	26.0384331	8.7850296	.001474926
679	461041	313046839	26.0576284	8.7893466	.001472754
680	462400	314432000	26.0768096	8.7936593	.001470586
681	463761	315821241	26.0959767	8.7979679	.001468429
682	465124	317214568	26.1151297	8.8022721	.001466276
683	466489	318611987	26.1342687	8.8065722	.001464129
684	467856	320013504	26.1533937	8.8108681	.001461988
685	469225	321419125	26.1725047	8.8151598	.001459854
686	470596	322828856	26.1916017	8.8194474	.001457726
687	471969	324242703	26.2106848	8.8237307	.001455604
688	473344	325660672	26.2297541	8.8280099	.001453488
689	474721	327082769	26.2488095	8.8322850	.001451379
690	476100	328509000	26.2678511	8.8365559	.001449275
691	477481	329939371	26.2868789	8.8408227	.001447173
692	478864	331373888	26.3058929	8.8450854	.001445087
693	480249	332812557	26.3248932	8.8493440	.001443001
694	481636	334255384	26.3438797	8.8535985	.001440922
695	483025	335702375	26.3628527	8.8578489	.001438849
696	484416	337153536	26.3818119	8.8620952	.001436782
697	485809	338608873	26.4007576	8.8663375	.001434720
698	487204	340068392	26.4196896	8.8705757	.001432665
699	488601	341532099	26.4386081	8.8748099	.001430615
700	490000	343000000	26.4575131	8.8790400	.001428571
701	491401	344472101	26.4764046	8.8832661	.001426534
702	492804	345948408	26.4952826	8.8874882	.001424501
703	494209	347428927	26.5141472	8.8917063	.001422475
704	495616	348913664	26.5329983	8.8959204	.001420455
705	497025	350402625	26.5518361	8.9001304	.001418440
706	498436	351895816	26.5706605	8.9043366	.001416431
707	499849	353393243	26.5894716	8.9085367	.001414427
708	501264	354894912	26.6082694	8.9127369	.001412429
709	502681	356400829	26.6270539	8.9169311	.001410437
710	504100	357911000	26.6458252	8.9211214	.001408451
711	505521	359425431	26.6645883	8.9253078	.001406470
712	506944	360944128	26.68333281	8.9294902	.001404494
713	508369	362467097	26.7020598	8.9336687	.001402525
714	509796	363994344	26.7207784	8.9378433	.001400560
715	511225	365525875	26.7394839	8.9420140	.001398601
716	512656	367061696	26.7581763	8.9461809	.001396648
717	514089	368601813	26.7768557	8.9503438	.001394700
718	515524	370146232	26.7955220	8.9545029	.001392758
719	516961	371694959	26.8141754	8.9586581	.001390821
720	518400	373248000	26.8328157	8.9628095	.001388889
721	519841	374805361	26.8514432	8.9669570	.001386963
722	521284	376367048	26.8700577	8.9711007	.001385042
723	522729	377933067	26.8886593	8.9752406	.001383126
724	524176	379503424	26.9072481	8.9793766	.001381215
725	525625	381078125	26.9258240	8.9835089	.001379310
726	527076	382657176	26.94441872	8.9876373	.001377410
727	528529	384240583	26.9629375	8.9917620	.001375516
728	529984	385828352	26.9814751	8.9958899	.001373636

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	√ Roots.	Reciprocals.
729	531441	387420489	27·0000000	9·0000000	001371742
730	532900	389017000	27·0185122	9·0041134	·001369863
731	534361	390617891	27·0370117	9·0082229	·001367989
732	535824	392223168	27·0554985	9·0123288	·001366120
733	537289	393832837	27·0739727	9·0164309	·001364256
734	538756	395446904	27·0924344	9·0205293	·001362398
735	540225	397065375	27·1108834	9·0246239	·001360544
736	541696	398688256	27·1293199	9·0287149	·001358696
737	543169	400315553	27·1477149	9·0328021	·001356852
738	544644	401947272	27·1661554	9·0368857	·001355014
739	546121	403583419	27·1845544	9·0409655	·001353180
740	547600	405224000	27·2029140	9·0450419	·001351351
741	549081	406869021	27·2213152	9·0491142	·001349528
742	550564	408518488	27·2396769	9·0531831	·001347709
743	552049	410172407	27·2580263	9·0572482	·001345895
744	553536	411830784	27·2763634	9·0613098	·001344086
745	555025	413493625	27·2946881	9·0653677	·001342282
746	556516	415160936	27·3130006	9·0694220	·001340483
747	558009	416832723	27·3313007	9·0734726	·001338688
748	559504	418508992	27·3495887	9·0775197	·001336898
749	561001	420189749	27·3678644	9·0815631	·001335113
750	562500	421875000	27·3861279	9·0856030	·001333333
751	564001	423564751	27·4043792	9·0896352	·001331558
752	565504	425259008	27·4226184	9·0936719	·001329787
753	567009	426957777	27·4408455	9·0977010	·001328021
754	568516	428661064	27·4590604	9·1017265	·001326260
755	570025	430368875	27·4772633	9·1057485	·001324503
756	571536	432081216	27·4954542	9·1097669	·001322751
757	573049	433798093	27·5136330	9·1137818	·001321004
758	574564	435519512	27·5317998	9·1177931	·001319261
759	576081	437245479	27·5499546	9·1218010	·001317523
760	577600	438976000	27·5680975	9·1258053	·001315789
761	579121	440711081	27·5862284	9·1298061	·001314060
762	580644	442450728	27·6043475	9·1338034	·001312336
763	582169	444194947	27·6224546	9·1377971	·001310616
764	583696	445943744	27·6405499	9·1417874	·001308901
765	585225	447697125	27·6586334	9·1457742	·001307190
766	586756	449455096	27·6767050	9·1497576	·001305483
767	588289	451217663	27·6947648	9·1537375	·001303781
768	589824	452984832	27·7128129	9·1577139	·001302083
769	591361	454756609	27·7308492	9·1616869	·001300390
770	592900	456533000	27·7488739	9·1656565	·001298701
771	594441	458314011	27·7668868	9·1696225	·001297017
772	595984	460099648	27·7848880	9·1735852	·001295337
773	597529	461889917	27·8028775	9·1775445	·001293661
774	599076	463684824	27·8208555	9·1815003	·001291990
775	600625	465484375	27·8388218	9·1854527	·001290323
776	602176	467288576	27·8567766	9·1894018	·001288660
777	603729	469097433	27·8747197	9·1933474	·001287001
778	605284	470910952	27·8926514	9·1972897	·001285347
779	606841	472729139	27·9105715	9·2012286	·001283697
780	608400	474552000	27·9284801	9·2051641	·001282051

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	∛ Roots.	Reciprocals.
781	609961	476379541	27-9463772	9-2090962	·001280410
782	611524	478211768	27-9642629	9-2130250	·001278772
783	613089	480048687	27-9821372	9-2169505	·001277139
784	614656	481890304	28-0000000	9-2208726	·001275510
785	616225	483736625	28-0178515	9-2247914	·001273885
786	617796	485587656	28-0356915	9-2287068	·001272265
787	619369	487443403	28-0535203	9-2326189	·001270648
788	620944	489303872	28-0713377	9-2365277	·001269036
789	622521	491169069	28-0891438	9-2404333	·001267427
790	624100	493039000	28-1069386	9-2443355	·001265823
791	625681	494913671	28-1247222	9-2482344	·001264223
792	627264	496793088	28-1424946	9-2521300	·001262626
793	628849	498677257	28-1602557	9-2560224	·001261034
794	630436	500566184	28-1780056	9-2599114	·001259446
795	632025	502459875	28-1957444	9-2637973	·001257862
796	633616	504358336	28-2134720	9-2676798	·001256281
797	635209	506261573	28-2311884	9-2715592	·001254705
798	636804	508169592	28-2488938	9-2754352	·001253133
799	638401	510082399	28-2665881	9-2793081	·001251564
800	640000	512000000	28-2842712	9-2831777	·001250000
801	641601	513922401	28-3019434	9-2870444	·001248439
802	643204	515849608	28-3196045	9-2909072	·001246883
803	644809	517781627	28-3372546	9-2947671	·001245330
804	646416	519718464	28-3548938	9-2986239	·001243781
805	648025	521660125	28-3725219	9-3024775	·001242236
806	649636	523606616	28-3901391	9-3063278	·001240695
807	651249	525557943	28-4077454	9-3101750	·001239157
808	652864	527514112	28-4253408	9-3140190	·001237624
809	654481	529475129	28-4429253	9-3178599	·001236094
810	656100	531441000	28-4604989	9-3216975	·001234568
811	657721	533411731	28-4780617	9-3255320	·001233046
812	659344	535387328	28-4956137	9-3293634	·001231527
813	660969	537367797	28-5131549	9-3331916	·001230012
814	662596	539353144	28-5306852	9-3370167	·001228501
815	664225	541343375	28-5482048	9-3408386	·001226994
816	665856	543338496	28-5657137	9-3446575	·001225499
817	667489	545338513	28-5832119	9-3484731	·001223990
818	669124	547343432	28-6006993	9-3522857	·001222494
819	670761	549353259	28-6181 60	9-3560952	·001221001
820	672400	551368000	28-6356421	9-3599016	·001219512
821	674041	553387661	28-6530976	9-3637049	·001218027
822	675684	555412248	28-6705424	9-3675051	·001216545
823	677329	557441767	28-6879716	9-3713022	·001215067
824	678976	559476224	28-7054002	9-3750963	·001213592
825	680625	561515625	28-7228132	9-3788873	·001212121
826	682276	563559976	28-7402157	9-3826752	·001210654
827	683929	565609283	28-7576077	9-3864600	·001209190
828	685584	567663552	28-7749891	9-3902419	·001207729
829	687241	569722789	28-7923601	9-3940206	·001206273
830	688900	571787000	28-8097206	9-3977964	·001204819
831	690561	573856191	28-8270706	9-4015691	·001203369
832	692224	575930368	28-8444102	9-4053387	·001201923

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	√ Roots.	Reciprocals
833	693889	578009537	28·8617394	9·4091054	·001200480
834	695556	580093704	28·8790582	9·4128690	·001199041
835	697225	582182875	28·8963666	9·4166297	·001197605
836	698896	584277056	28·9136646	9·4203873	·001196172
837	700569	586376253	28·9309523	9·4241420	·001194743
838	702244	588480472	28·9482297	9·4278936	·001193317
839	703921	590589719	28·9654967	9·4316423	·001191895
840	705600	592704000	28·9827535	9·4353800	·001190476
841	707281	594823321	29·0000000	9·4391307	·001189061
842	708964	596947688	29·0172363	9·4428704	·001187648
843	710649	599077107	29·0344623	9·4466072	·001186240
844	712336	601211584	29·0516781	9·4503410	·001184834
845	714025	603351125	29·0688837	9·4540719	·001183432
846	715716	605495736	29·0860791	9·4577999	·001182033
847	717409	607645423	29·1032644	9·4615249	·001180638
848	719104	609800192	29·1204396	9·4652470	·001179245
849	720801	611960049	29·1376046	9·4689661	·001177856
850	722500	614125000	29·1547595	9·4726824	·001176471
851	724201	616295051	29·1719043	9·4763957	·001175088
852	725904	618470208	29·1890390	9·4801061	·001173709
853	727609	620650477	29·2061637	9·4838136	·001172333
854	729316	622835864	29·2232784	9·4875182	·001170960
855	731025	625026375	29·2403830	9·4912200	·001169591
856	732736	627222016	29·2574777	9·4949188	·001168224
857	734449	629422793	29·2745623	9·4986147	·001166861
858	736164	631628712	29·2916370	9·5023078	·001165501
859	737881	633839779	29·3087018	9·5059980	·001164144
860	739600	636056000	29·3257566	9·5096854	·001162791
861	741321	638277381	29·3428015	9·5133699	·001161440
862	743044	640503928	29·3598365	9·5170515	·001160093
863	744769	642735647	29·3768616	9·5207303	·001158749
864	746496	644972544	29·3938769	9·5244063	·001157407
865	748225	647214625	29·4108823	9·5280794	·001156069
866	749956	649461896	29·4278779	9·5317497	·001154734
867	751689	651714363	29·4448637	9·5354172	·001153403
868	753424	653972032	29·4618397	9·5390818	·001152074
869	755161	656234909	29·4788059	9·5427437	·001150748
870	756900	658503000	29·4957624	9·5464027	·001149425
871	758641	660776311	29·5127091	9·5500589	·001148106
872	760384	663054848	29·5296461	9·5537123	·001146789
873	762129	665338617	29·5465734	9·5573630	·001145475
874	763876	667627624	29·5634910	9·5610108	·001144165
875	765625	669921875	29·5803989	9·5646559	·001142857
876	767376	672221376	29·5972972	9·5682782	·001141553
877	769129	674526133	29·6141858	9·5719377	·001140251
878	770884	676836152	29·6310648	9·5755745	·001138952
879	772641	679151439	29·6479342	9·5792085	·001137656
880	774400	681472000	29·6647939	9·5828397	·001136364
881	776161	683797841	29·6816442	9·5864682	·001135074
882	777924	686128968	29·6984848	9·5900937	·001133787
883	779689	688465387	29·7153159	9·5937169	·001132503
884	781456	690807104	29·7321375	9·5973373	·001131222

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	√ Roots.	Reciprocals.
885	783225	693154125	29-7489496	9-6009548	-001129944
886	784996	695506456	29-7657521	9-6045696	-001128668
887	786769	697864103	29-7825452	9-6081817	-001127396
888	788544	700227072	29-7993289	9-6117911	-001126126
889	790321	702595369	29-8161030	9-6153977	-001124859
890	792100	704969000	29-8328678	9-6190017	-001123596
891	793881	707347971	29-8496231	9-6226030	-001122334
892	795664	707932288	29-8663690	9-6262016	-001121076
893	797449	712121957	29-8831056	9-6297975	-001119821
894	799236	714516984	29-8998328	9-6333907	-001118568
895	801025	716917375	29-9165506	9-6369812	-001117818
896	802816	719323136	29-9332591	9-6405690	-001116071
897	804609	721734273	29-9499583	9-6441542	-001114827
898	806404	724150792	29-9666481	9-6477367	-001113586
899	808201	726572699	29-9833287	9-6513166	-001112347
900	810000	729000000	30-0000000	9-6548938	-001111111
901	811801	731432701	30-0166621	9-6584684	-001109878
902	813604	733870808	30-0333148	9-6620403	-001108647
903	815409	736314327	30-0499584	9-6656096	-001107420
904	817216	738763264	30-0665928	9-6691762	-001106195
905	819025	741217625	30-0832179	9-6727403	-001104972
906	820836	743677416	30-0998339	9-6763017	-001103753
907	822649	746142643	30-1164407	9-6798604	-001102536
908	824464	748613312	30-1330383	9-6834166	-001101322
909	826281	751089429	30-1496269	9-6869701	-001100110
910	828100	753571000	30-1662063	9-6905211	-001098901
911	829921	756058031	30-1827765	9-6940694	-001097695
912	831744	758550828	30-1993377	9-6976151	-001096491
913	833569	761048497	30-2158899	9-7011583	-001095290
914	835396	763551944	30-2324329	9-7046989	-001094092
915	837225	766060875	30-2489669	9-7082369	-001092896
916	839056	768575296	30-2654919	9-7117723	-001091703
917	840889	771095213	30-2820079	9-7153051	-001090513
918	842724	773620632	30-2985148	9-7188354	-001089325
919	844561	776151559	30-3150128	9-7223631	-001088139
920	846400	778688000	30-3315018	9-7258883	-001086957
921	848241	781229961	30-3479818	9-7294109	-001085776
922	850084	783777448	30-3644529	9-7329309	-001084599
923	851929	786330467	30-3809151	9-7364484	-001083423
924	853776	788889024	30-3973683	9-7399634	-001082251
925	855625	791453125	30-4138127	9-7434758	-001081081
926	857476	794022776	30-4302481	9-7469857	-001079914
927	859329	796597983	30-4466747	9-7504930	-001078749
928	861184	799178752	30-4630924	9-7539979	-001077586
929	863041	801765089	30-4795013	9-7575002	-001076426
930	864900	804357000	30-4959014	9-7610001	-001075269
931	866761	806954491	30-5122926	9-7644974	-001074114
932	868624	809557568	30-5286750	9-7679922	-001072961
933	870489	812166237	30-5450487	9-7714845	-001071811
934	872356	814780504	30-5614136	9-7749743	-001070664
935	874225	817400375	30-5777697	9-7784616	-001069519
936	876096	820025856	30-5941171	9-7819466	-001068376

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	$\sqrt{\text{Roots.}}$	$\sqrt[3]{\text{Roots.}}$	Reciprocals.
937	877969	822656953	30.6104557	9.7854288	.001067236
938	879844	825293672	30.6267857	9.7889087	.001066098
939	881721	827936019	30.6431069	9.7923861	.001064963
940	883600	830584000	30.6594194	9.7958611	.001063830
941	885481	833237621	30.6757233	9.7993336	.001062699
942	887364	835896888	30.6920185	9.8028036	.001061571
943	889249	838561807	30.7083051	9.8062711	.001060445
944	891136	841232384	30.7245830	9.8097362	.001059322
945	893025	843908625	30.7408523	9.8131989	.001058201
946	894916	846590536	30.7571130	9.8166591	.001057082
947	896809	849278123	30.7733651	9.8201169	.001055966
948	898704	851971392	30.7896086	9.8235723	.001054852
949	900601	854670349	30.8058436	9.8270252	.001053741
950	902500	857375000	30.8220700	9.8304757	.001052632
951	904401	860085351	30.8382879	9.8339238	.001051525
952	906304	862801408	30.8544972	9.8373695	.001050420
953	908209	865523177	30.8706981	9.8408127	.001049318
954	910116	868250664	30.8868904	9.8442536	.001048218
955	912025	870983875	30.9030743	9.8476920	.001047120
956	913936	873722816	30.9192477	9.8511280	.001046025
957	915849	876467493	30.9354166	9.8545617	.001044932
958	917764	879217912	30.9515751	9.8579929	.001043841
959	919681	881974079	30.9677251	9.8614218	.001042753
960	921600	884736000	30.9838668	9.8648483	.001041667
961	923521	887503681	31.0000000	9.8682724	.001040583
962	925444	890277128	31.0161248	9.8716941	.001039501
963	927369	893056347	31.0322413	9.8751135	.001038422
964	929296	895841344	31.0483494	9.8785305	.001037344
965	931225	898632125	31.0644491	9.8819451	.001036269
966	933156	901428696	31.0805405	9.8853574	.001035197
967	935089	904231063	31.0966236	9.8887673	.001034126
968	937024	907039232	31.1126984	9.8921749	.001033058
969	938961	909853209	31.1287648	9.8955801	.001031992
970	940900	912673000	31.1448230	9.8989830	.001030928
971	942841	915498611	31.1608729	9.9023835	.001029866
972	944784	918330048	31.1769145	9.9057817	.001028807
973	946729	921167317	31.1929479	9.9091776	.001027749
974	948676	924010424	31.2089731	9.9125712	.001026694
975	950625	926859375	31.2249900	9.9159624	.001025641
976	952576	929714176	31.2409987	9.9193513	.001024590
977	954529	932574833	31.2569992	9.9227379	.001023541
978	956484	935441352	31.2729915	9.9261222	.001022495
979	958441	938313739	31.2889757	9.9295042	.001021450
980	960400	941192000	31.3049517	9.9328839	.001020408
981	962361	944076141	31.3209195	9.9362613	.001019363
982	964324	946966168	31.3368792	9.9396363	.001018330
983	966289	949862087	31.3528308	9.9430092	.001017294
984	968256	952763904	31.3687743	9.9463797	.001016260
985	970225	955671625	31.3847097	9.9497479	.001015228
986	972196	958585256	31.4006369	9.9531138	.001014199
987	974169	961504803	31.4165561	9.9564775	.001013171
988	976144	964430272	31.4324673	9.9598389	.001012146

TABLES OF SQUARES, CUBES, SQUARE AND CUBE ROOTS.

Number.	Squares.	Cubes.	√ Roots.	∛ Roots.	Reciprocals.
989	978121	967361669	31·4483704	9·9631981	·001011122
990	980100	970299000	31·4642654	9·9665549	·001010101
991	982081	973242271	31·4801525	9·9699055	·001009082
992	984064	976191488	31·4960315	9·9732619	·001008065
993	986049	979146657	31·5119025	9·9766120	·001007049
994	988036	982107784	31·5277655	9·9799599	·001006036
995	990025	985074875	31·5436206	9·9833055	·001005025
996	992016	988047936	31·5594677	9·9866488	·001004016
997	994009	991026973	31·5753068	9·9899900	·001003009
998	996004	994011992	31·5911380	9·9933289	·001002004
999	998001	997002999	31·6069613	9·9966656	·001001001
1000	1000000	1000000000	31·6227766	10·0000000	·001000000
1001	1002001	1003003001	31·6385840	10·0033222	·0009990010
1002	1004004	1006012008	31·6543866	10·0066622	·0009980040
1003	1006009	1009027027	31·6701752	10·0099899	·0009970090
1004	1008016	1012048064	31·6859590	10 0133155	·0009960159
1005	1010025	1015075125	31·7017349	10·0166389	·0009950249
1006	1012036	1018108216	31·7175030	10·0199601	·0009940358
1007	1014049	1021147343	31·7332633	10·0232791	·0009930487
1008	1016064	1024192512	31·7490157	10·0265958	·0009920635
1009	1018081	1027243729	31·7647603	10·0299104	·0009910803
1010	1020100	1030301000	31·7804972	10·0332228	·0009900990
1011	1022121	1033364331	31·7962262	10·0365330	·0009891197
1012	1024144	1036433728	31·8119474	10·0398410	·0009881423
1013	1026169	1039509197	31·8276609	10·0431469	·0009871668
1014	1028196	1042590744	31·8433666	10·0464506	·0009861933
1015	1030225	1045678375	31·8590646	10·0497521	·0009852217
1016	1032256	1048772096	31·8747549	10·0530514	·0009842520
1017	1034289	1051871913	31·8904374	10·0563485	·0009832842
1018	1036324	1054977832	31·9061123	10·0596435	·0009823183
1019	1038361	1058089859	31·9217794	10·0629364	·0009813543
1020	1040400	1061208000	31·9374388	10·0662271	·0009803922
1021	1042441	1064332261	31·9530906	10·0695156	·0009794319
1022	1044484	1067462648	31·9687347	10·0728020	·0009784736
1023	1046529	1070599167	31·9843712	10·0760863	·0009775171
1024	1048576	1073741824	32·0000000	10·0793684	·0009765625
1025	1050625	1076890625	32·0156212	10·0826484	·0009756098
1026	1052676	1080045576	32·0312348	10·0859262	·0009746589
1027	1054729	1083206683	32·0468407	10·0892019	·0009737098
1028	1056784	1086373952	32·0624391	10·0924755	·0009727626
1029	1058841	1089547389	32·0780298	10·0957469	·0009718173
1030	1060900	1092727000	32·0936131	10·0990163	·0009708738
1031	1062961	1095912791	32·1091887	10·1022835	·0009699321
1032	1065024	1099104768	32·1247568	10·1055487	·0009689922
1033	1067089	1102302937	32·1403173	10·1088117	·0009680542
1034	1069156	1105507304	32·1558704	10·1120726	·0009671180
1035	1071225	1108717875	32·1714159	10·1153314	·0009661836
1036	1073296	1111934656	32·1869539	10·1185882	·0009652510
1037	1075369	1115157653	32·2024844	10·1218428	·0009643202
1038	1077444	1118386872	32·2180074	10·1250953	·0009633911
1039	1079521	1121622319	32·2335229	10·1283457	·0009624639
1040	1081600	1124864000	32·2490310	10·1315941	·0009615385

WROUGHT IRON BEAMS.

Safe Load in tons of 2,000 lbs. when equally distributed.

LENGTH IN FEET BETWEEN SUPPORTS.	15 inch. 200 lbs. to yd.	15 inch. 150 lbs to yd.	12 $\frac{1}{4}$ inch. 170 lbs. to yd.	12 $\frac{1}{4}$ inch. 126 lbs. to yd.	10 $\frac{1}{2}$ inch. 135 lbs. to yd.	10 $\frac{1}{2}$ inch. 106 lbs. to yd.	10 $\frac{1}{2}$ inch. 90 lbs. to yd.	9 inch. 150 lbs. to yd.
8	51.2	37.8	36.5	26.0	22.3	19.4	16.6	24.6
9	45.6	33.6	32.6	23.1	19.8	17.2	14.8	21.8
10	41.0	30.2	29.2	20.8	17.8	15.5	13.3	19.7
11	37.2	27.4	26.6	18.8	16.2	14.0	12.1	17.8
12	34.2	25.2	24.3	17.3	14.8	12.9	11.1	16.4
13	31.6	23.2	22.4	16.0	13.7	11.8	10.2	15.2
4	29.3	21.6	20.9	14.9	12.7	11.1	9.5	14.1
15	27.4	20.0	19.4	13.8	11.8	10.2	8.9	13.2
16	25.6	18.9	18.3	13.0	11.1	9.7	8.3	12.3
17	24.1	17.8	17.2	12.2	10.5	9.1	7.7	11.6
18	22.8	16.8	16.2	11.5	9.9	8.6	7.4	10.9
19	21.6	15.9	15.4	10.9	9.3	8.1	7.0	10.3
20	20.5	15.1	14.6	10.4	8.9	7.7	6.7	9.6
21	19.5	14.4	13.9	9.9	8.5	7.3	6.3	9.3
22	18.6	13.7	13.3	9.4	8.1	7.0	6.0	8.9
23	17.8	13.1	12.7	9.0	7.7	6.7	5.8	8.5
24	17.1	12.6	12.2	8.7	7.4	6.5	5.6	8.2
25	16.4	12.1	11.7	8.3	7.1	6.2	5.3	7.9
26	15.5	11.6	11.2	8.0	6.8	5.9	5.1	7.6
27	15.2	11.2	10.8	7.7	6.6	5.7	4.9	7.3
28	14.6	10.8	10.4	7.4	6.3	5.5	4.8	7.0
29	14.1	10.4	10.0	7.1	6.1	5.3	4.6	6.8
30	13.7	10.0	9.7	6.9	5.9	5.1	4.4	6.6

WROUGHT IRON BEAMS.

Safe Load in tons of 2,000 lbs. when equally distributed.

LENGTH IN FEET BETWEEN SUPPORTS.	9 inch, 125 lbs. to yd.	9 inch, 85 lbs. to yd.	9 inch, 70 lbs. to yd.	8 inch, 81 lbs. to yd.	8 inch, 65 lbs. to yd.	7 inch, 60 lbs. to yd.	7 inch, 55 lbs. to yd.	6 inch, 120 lbs. to yd.
8	18.4	13.5	11.5	11.8	9.2	9.0	6.6	11.8
9	16.4	12.0	10.2	10.5	8.2	8.0	6.0	10.5
10	14.7	10.8	9.2	9.4	7.4	7.2	5.4	9.5
11	13.4	9.8	8.4	8.5	6.8	6.5	4.8	8.1
12	12.3	9.0	7.7	7.8	6.2	6.0	4.5	7.8
13	11.3	8.3	7.0	7.2	5.7	5.5	4.2	7.3
14	10.5	7.7	6.7	6.7	5.3	5.1	3.9	6.8
15	9.8	7.2	6.2	6.2	4.9	4.8	3.6	6.3
16	9.2	6.7	5.7	5.9	4.6	4.5	3.4	5.9
17	8.6	6.3	5.4	5.5	4.3	4.2	3.2	5.5
18	8.2	6.0	5.1	5.2	4.1	4.0	3.0	5.2
19	7.7	5.7	4.8	5.0	3.9	3.8	2.8	5.0
20	7.4	5.4	4.6	4.7	3.7	3.6	2.7	4.7
21	7.0	5.1	4.4	4.5	3.5	3.4	2.5	4.4
22	6.7	4.9	4.2	4.2	3.4	3.2	2.4	4.3
23	6.4	4.7	4.0	4.1	3.2	3.1	2.3	4.1
24	6.1	4.5	3.8	3.9	3.1	3.0	2.2	3.9
25	5.9	4.3	3.6	3.7	2.9	2.9	2.1	3.8
26	5.7	4.1	3.5	3.6	2.8	2.8	2.1	3.6
27	5.5	3.9	3.4	3.5	2.7	2.7	2.0	3.5
28	5.3	3.8	3.3	3.3	2.6	2.6	1.9	3.4
29	5.1	3.7	3.2	3.2	2.5	2.5	1.8	3.2
30	4.9	3.6	3.1	3.1	2.4	2.4	1.8	3.1

WROUGHT IRON BEAMS.

Safe Load in Tons of 2,000 lbs. when equally distributed.

LENGTH IN FEET BETWEEN SUPPORTS	6 inch, 90 lbs. to yd.	6 inch, 50 lbs. to yd.	6 inch, 40 lbs. to yd.	5 inch, 40 lbs. to yd.	5 inch, 36 lbs. to yd.	5 inch, 30 lbs. to yd.	4 inch, 37 lbs. to yd.	4 inch, 30 lbs. to yd.
8	9.1	5.6	4.4	3.4	3.1	2.6	2.5	1.8
9	8.1	5.0	3.9	3.0	2.8	2.4	2.2	1.6
10	7.3	4.5	3.5	2.7	2.5	2.1	2.0	1.5
11	6.6	4.1	3.2	2.4	2.3	1.9	1.8	1.4
12	6.0	3.7	2.9	2.3	2.0	1.7	1.7	1.3
13	5.6	3.4	2.7	2.1	1.9	1.6	1.6	1.2
14	5.2	3.2	2.5	1.9	1.8	1.5	1.4	1.1
15	4.8	3.0	2.3	1.8	1.7	1.4	1.3	1.0
16	4.5	2.8	2.2	1.7	1.6	1.3	1.2	1.0
17	4.3	2.6	2.0	1.6	1.5	1.2	1.1	.9
18	4.0	2.5	1.9	1.5	1.4	1.2	1.1	.9
19	3.8	2.4	1.8	1.4	1.3	1.1	1.0	.8
20	3.6	2.2	1.7	1.3	1.2	1.0	1.0	.8
21	3.4	2.1	1.6	1.3	1.2	1.0	1.0	.8
22	3.3	2.0	1.6	1.2	1.1	.9	.9	.7
23	3.1	1.9	1.5	1.1	1.1	.9	.9	.7
24	3.0	1.8	1.5	1.1	1.0	.8	.8	.7
25	2.9	1.8	1.4	1.1	1.0	.8	.8	.7
26	2.8	1.7	1.3	1.0	.9	.8	.8	.6
27	2.6	1.6	1.3	1.0	.9	.7	.7	.6
28	2.6	1.6	1.2	.9	.9	.7	.7	.6
29	2.5	1.5	1.2	.9	.8	.7	.7	.6
30	2.4	1.5	1.1	.9	.8	.7	.7	.6

WROUGHT IRON CHANNELS.

Safe Load in Tons of 2,000 lbs. when equally distributed.

LENGTH IN FEET BETWEEN SUPPORTS.	15 inch, 180 lbs. to yd.	15 inch, 120 lbs. to yd.	12½ inch, 140 lbs. to yd.	12½ inch 70 lbs. to yd.	10½ inch, 60 lbs. to yd.	9 inch, 70 lbs. to yd.	9 inch, 50 lbs. to yd.	8 inch, 45 lbs. to yd.
8	43.0	27.6	26.2	13.8	9.3	10.4	7.1	6.1
9	38.7	24.5	23.3	12.2	8.2	8.9	6.4	5.4
10	34.4	22.1	21.0	11.0	7.4	8.0	5.7	4.9
11	31.2	20.0	19.0	10.0	6.7	7.3	5.2	4.4
12	28.6	18.4	17.5	9.2	6.2	6.7	4.8	4.1
13	26.4	17.0	16.1	8.5	5.7	6.2	4.4	3.8
14	24.5	15.8	15.0	7.9	5.2	5.7	4.1	3.5
15	22.9	14.7	14.0	7.3	4.9	5.4	3.8	3.3
16	21.5	13.8	13.1	6.9	4.6	5.0	3.6	3.0
17	20.2	13.0	12.3	6.5	4.4	4.7	3.4	2.9
18	19.1	12.2	11.6	6.1	4.1	4.5	3.2	2.7
19	18.1	11.6	11.0	5.8	3.9	4.2	3.0	2.6
20	17.2	11.0	10.5	5.5	3.7	4.0	2.9	2.4
21	16.4	10.5	10.0	5.2	3.5	3.8	2.7	2.3
22	15.6	10.0	9.5	5.0	3.4	3.6	2.6	2.2
23	14.9	9.6	9.1	4.8	3.2	3.5	2.5	2.1
24	14.3	9.2	8.7	4.6	3.1	3.4	2.4	2.0
25	13.7	8.8	8.4	4.4	3.0	3.2	2.3	1.9
26	13.2	8.5	8.1	4.2	2.9	3.1	2.2	1.8
27	12.9	8.2	7.8	4.1	2.8	3.0	2.1	1.8
28	12.3	7.9	7.5	4.0	2.7	2.9	2.0	1.7
29	11.8	7.7	7.2	3.8	2.6	2.8	1.9	1.7
30	11.4	7.4	7.0	3.7	2.5	2.7	1.9	1.6

CAST IRON COLUMNS.

Safe load in Tons of 2,000 lbs. Factor of safety 6 to 1.

LENGTH IN FEET.	$\frac{3}{8}$ in. Thick.	$\frac{1}{2}$ in. Thick.	$\frac{5}{8}$ in. Thick.	$\frac{3}{4}$ in. Thick.	$\frac{7}{8}$ in. Thick.	1 in. Thick.	$1\frac{1}{4}$ in. Thick.	$1\frac{1}{2}$ in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.
COLUMNS 3" DIAMETER								
4	15.7	19.8	23.5	26.8	29.5	31.7	34.7	35.7
5	13.8	17.4	20.7	23.5	25.9	27.9	30.5	31.4
6	12.0	15.2	18.0	20.6	22.7	24.4	26.7	27.4
7	10.4	13.2	15.7	17.9	19.7	21.2	23.2	23.8
8	9.0	11.5	13.6	15.5	17.0	18.3	20.1	20.6
9	7.8	10.0	11.8	13.5	14.8	16.0	17.5	17.9
10	6.9	8.7	10.3	11.8	13.0	13.9	15.3	15.7
COLUMNS 4" DIAMETER.								
6	20.3	26.0	31.4	36.3	40.8	44.7	51.3	56.0
7	18.3	23.6	28.5	32.9	36.9	40.5	46.4	50.7
8	16.6	21.3	25.7	29.7	33.3	36.5	41.9	45.7
9	14.9	19.2	23.1	26.6	30.0	32.9	37.7	41.1
10	13.4	17.2	20.8	23.9	27.0	29.6	33.9	37.0
11	12.0	15.5	18.7	21.5	24.2	26.6	30.5	33.2
12	10.8	13.9	16.8	19.3	21.8	23.9	27.4	29.9
COLUMNS 5" DIAMETER.								
8	24.8	32.2	39.2	46.0	52.0	57.4	67.4	75.4
9	22.9	29.8	36.2	42.2	47.7	52.9	62.0	69.4
10	21.1	27.5	33.3	38.9	44.0	48.8	57.1	64.0
11	19.4	25.2	30.6	35.7	40.3	44.7	52.4	58.7
12	17.9	23.2	28.2	32.9	37.2	41.2	48.3	54.1
13	16.4	21.3	25.9	30.2	34.1	37.8	44.3	49.6
14	15.1	19.6	23.8	27.8	31.4	34.8	40.8	45.7

CAST IRON COLUMNS.

Safe Load in Tons of 2,000 lbs. Factor of Safety 6 to 1.

LENGTH IN FEET.	$\frac{1}{8}$ in. Thick.	$\frac{5}{8}$ in. Thick.	$\frac{3}{4}$ in. Thick.	$\frac{7}{8}$ in. Thick.	1 in. Thick.	$1\frac{1}{4}$ in. Thick.	$1\frac{1}{2}$ in. Thick.	$1\frac{3}{4}$ in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.

COLUMNS 6" DIAMETER.								
10	38.4	46.8	54.9	62.6	69.8	82.8	94.1	103.7
11	35.9	43.8	51.3	58.5	65.2	77.4	88.0	97.0
12	33.5	41.0	48.0	54.7	61.0	72.3	82.3	90.7
13	31.2	38.1	44.7	50.9	56.7	67.3	76.6	84.4
14	29.1	35.6	41.7	47.5	53.0	62.8	71.4	78.7
15	27.1	33.1	38.8	44.2	49.3	58.5	66.6	73.4
16	25.2	30.8	36.1	41.1	45.9	54.4	61.9	68.2
17	23.6	28.8	33.8	38.5	42.9	50.9	57.9	63.8
18	22.0	26.8	31.4	35.6	39.9	47.3	53.9	59.3
19	20.6	25.1	29.4	33.5	37.4	44.4	50.5	55.6
20	19.2	23.4	27.5	31.3	34.9	41.4	47.1	51.9

COLUMNS 7" DIAMETER.								
11	47.2	57.8	68.0	77.8	87.1	104.3	119.7	133.3
12	44.5	54.6	64.2	73.4	82.2	98.5	113.0	125.8
13	42.0	51.5	60.6	69.2	77.5	92.8	106.5	118.6
14	39.6	48.6	57.1	65.3	73.1	87.4	100.6	111.9
15	37.3	45.7	53.8	61.5	68.8	82.3	94.6	105.3
16	35.1	43.1	50.7	57.9	64.8	77.5	89.2	99.3
17	33.0	40.4	47.6	54.4	60.9	72.8	83.7	93.2
18	31.1	38.2	44.9	51.4	57.5	68.7	79.1	88.0
19	29.2	35.8	42.1	48.2	53.9	64.5	74.1	82.5
20	27.6	33.8	39.8	45.5	50.9	60.9	69.9	77.7
21	25.9	31.8	37.4	42.8	47.9	57.2	65.8	73.3

CAST IRON COLUMNS.

Safe Load in Tons of 2,000 lbs Factor of Safety 6 to 1.

LENGTH IN FEET.	$\frac{5}{8}$ in. Thick.	$\frac{3}{4}$ in. Thick.	$\frac{7}{8}$ in. Thick.	1 in. Thick.	$1\frac{1}{4}$ in. Thick.	$1\frac{1}{2}$ in. Thick.	$1\frac{3}{4}$ in. Thick.	2 in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.

COLUMNS 8" DIAMETER.

12	68.8	81.1	93.0	104.4	125.9	145.5	163.2	179.1
13	65.3	77.0	88.3	99.2	119.6	138.1	154.9	170.0
14	62.3	73.4	84.2	94.6	114.0	131.7	147.7	162.1
15	59.1	69.7	79.9	89.7	108.2	125.0	140.2	153.8
16	56.2	66.3	76.0	83.3	102.9	118.8	133.3	146.3
17	53.1	62.7	71.9	80.7	97.3	112.4	126.1	138.4
18	50.5	59.6	68.4	76.7	92.5	106.9	119.9	131.6
19	47.9	56.5	64.8	72.8	87.7	101.4	113.7	124.8
20	45.5	53.6	61.5	69.0	83.2	96.2	107.9	118.4
21	43.0	50.7	58.2	65.3	78.7	91.0	102.0	112.0
22	40.8	48.2	55.2	62.0	74.8	86.4	96.9	106.3

COLUMNS 9" DIAMETER

13	79.8	94.3	108.3	121.8	147.6	171.4	193.3	213.3
14	76.1	90.0	103.4	116.3	140.9	163.6	184.6	203.6
15	73.0	86.3	99.1	111.6	135.1	156.9	176.9	195.3
16	69.9	82.6	94.9	105.8	129.3	150.2	169.4	186.9
17	66.4	78.5	90.2	104.0	122.9	142.7	161.0	177.7
18	63.8	75.4	86.6	99.8	118.1	137.1	154.7	170.6
19	60.8	71.9	82.6	95.2	112.6	130.8	147.5	162.7
20	58.0	68.6	78.8	90.8	107.4	124.7	140.7	155.2
21	55.4	65.5	75.2	86.7	102.6	119.1	134.3	148.2
22	52.8	62.5	71.7	82.6	97.7	113.4	128.0	141.2
23	50.6	59.7	68.8	79.0	93.4	108.5	122.4	135.0
24	48.0	56.8	65.2	75.1	88.9	103.2	116.4	128.4

CAST IRON COLUMNS.

Safe Load in Tons of 2,000 lbs. Factor of Safety 6 to 1.

LENGTH IN FEET.	$\frac{3}{4}$ in. Thick.	1 in. Thick.	$1\frac{1}{4}$ in. Thick.	$1\frac{1}{2}$ in. Thick.	$1\frac{3}{4}$ in. Thick.	2 in. Thick.	$2\frac{1}{4}$ in. Thick.	$2\frac{1}{2}$ in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.

COLUMNS 10" DIAMETER.

14	107.5	139.4	169.4	197.4	223.2	247.8	270.1	290.4
15	103.6	134.3	163.3	190.6	215.9	238.8	260.2	279.8
16	99.4	129.0	156.7	182.7	206.8	229.2	249.8	268.6
17	95.5	123.9	150.5	175.5	198.6	220.2	240.0	258.0
18	91.8	119.1	144.7	168.7	191.0	211.6	230.7	248.0
19	88.1	114.2	138.8	161.8	183.2	203.1	221.3	238.0
20	84.6	109.7	133.3	155.4	176.0	195.0	212.6	228.6
21	80.9	104.9	127.5	148.6	168.2	186.5	203.3	218.6
22	78.3	101.6	123.4	143.8	162.8	180.4	196.7	211.5
23	74.6	96.7	117.6	137.0	155.1	171.9	187.4	201.5
24	71.3	92.5	112.4	131.0	148.3	164.4	179.2	192.6

COLUMNS 11" DIAMETER.

14	124.6	162.1	197.6	231.0	262.4	291.8	319.1	344.5
15	120.7	157.1	191.4	223.8	254.3	282.7	309.2	333.8
16	116.6	151.8	184.9	216.2	245.6	273.1	298.7	322.4
17	112.8	146.7	178.8	209.1	237.5	264.1	288.9	311.8
18	108.7	141.4	172.3	201.5	228.9	254.4	278.3	300.4
19	104.8	136.4	166.2	194.3	220.7	245.4	268.4	289.7
20	101.4	131.3	160.0	187.1	212.6	236.4	258.5	280.0
21	97.5	126.3	153.9	180.0	204.5	227.3	248.6	268.4
22	94.1	121.9	148.6	173.7	197.3	219.4	240.0	259.0
23	90.5	117.2	142.8	167.0	189.7	210.9	230.7	249.0
24	87.1	112.8	137.5	160.7	182.6	203.0	222.0	239.7

CAST IRON COLUMNS.

Safe Load in Tons of 2,000 lbs. Factor of Safety 6 to 1.

LENGTH IN FEET.	$\frac{3}{4}$ in. Thick.	1 in. Thick.	$1\frac{1}{4}$ in. Thick.	$1\frac{1}{2}$ in. Thick.	$1\frac{3}{4}$ in. Thick.	2 in. Thick.	$2\frac{1}{4}$ in. Thick.	3 in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.
COLUMNS 12" DIAMETER.								
15	137.9	179.7	230.0	257.3	293.0	326.7	388.0	441.0
16	133.9	174.5	223.3	249.9	284.6	317.3	376.8	428.3
17	129.9	169.3	216.7	242.5	276.1	308.9	365.6	415.6
18	125.9	164.2	210.0	235.0	267.7	298.4	354.4	402.9
19	121.7	158.6	203.0	227.1	258.6	288.4	342.5	389.3
20	117.7	153.4	196.3	219.7	250.2	279.0	331.3	376.6
21	114.0	148.6	190.1	212.8	242.3	270.2	320.8	364.7
22	110.2	143.4	183.5	205.3	233.9	260.7	309.6	352.0
23	106.3	139.0	177.3	198.4	225.9	251.9	299.2	340.1
24	102.9	134.1	171.6	192.0	218.6	243.8	289.5	329.1
25	99.2	129.3	165.4	185.1	210.8	235.0	279.0	317.2

COLUMNS 13" DIAMETER.

15	155.0	202.5	247.8	291.0	332.1	371.2	442.9	506.1
16	150.9	197.2	241.3	283.4	323.5	361.5	431.3	492.9
17	147.2	192.3	235.3	276.4	315.4	353.5	420.6	480.7
18	143.2	187.0	228.9	268.8	306.8	342.7	409.9	467.5
19	139.1	181.7	222.4	261.2	298.1	333.2	397.5	454.3
20	135.1	176.4	215.9	253.6	289.5	323.5	386.0	441.0
21	130.7	170.8	209.0	245.5	280.2	313.1	373.6	427.0
22	126.7	165.5	202.6	237.9	271.5	303.4	362.0	412.9
23	122.9	160.6	196.6	230.9	263.5	294.5	351.3	402.0
24	119.2	155.7	190.6	223.8	255.4	285.5	340.6	389.3
25	115.4	150.8	184.6	216.8	247.4	276.5	329.9	377.0

CAST IRON COLUMNS.

Safe Load in Tons of 2,000 lbs. Factor of Safety 6 to 1.

LENGTH IN FEET.	$\frac{3}{4}$ in. Thick.	1 in. Thick.	$1\frac{1}{4}$ in. Thick.	$1\frac{1}{2}$ in. Thick.	$1\frac{3}{4}$ in. Thick.	2 in. Thick.	$2\frac{1}{2}$ in. Thick.	3 in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.

COLUMNS 14" DIAMETER.								
16	168.2	220.5	270.0	317.5	363.0	406.4	486.8	558.7
17	164.1	215.1	263.5	309.8	354.2	396.6	475.1	545.3
18	160.4	210.2	257.5	302.7	346.1	387.5	464.2	532.9
19	156.5	204.9	251.0	295.1	337.4	377.7	453.0	519.4
20	152.3	199.6	244.5	287.4	328.6	367.9	440.8	505.9
21	148.2	194.3	238.0	279.8	319.9	358.1	429.0	492.4
22	144.5	189.4	232.0	272.7	312.1	349.0	418.2	480.0
23	139.8	183.5	224.5	263.9	301.7	337.7	404.6	464.4
24	136.0	178.3	218.5	256.8	293.6	328.7	393.8	452.0
25	132.3	173.4	212.4	249.7	285.5	319.6	383.0	439.6
26	128.2	168.1	205.9	242.1	276.8	309.9	371.2	426.1

COLUMNS 15" DIAMETER.								
16	185.8	243.3	298.6	352.3	403.1	451.8	543.0	625.0
17	181.8	238.0	292.1	344.6	394.4	442.0	531.2	611.9
18	177.7	232.8	285.7	337.0	385.6	432.2	519.5	598.3
19	173.7	227.5	279.2	329.3	376.9	422.4	507.7	584.7
20	169.7	222.2	272.7	321.7	368.1	412.6	495.9	571.2
21	165.7	216.9	266.2	314.0	359.4	402.4	484.1	557.6
22	161.6	211.6	259.7	306.4	350.6	393.0	472.3	544.0
23	157.6	206.4	253.3	298.7	341.9	383.2	460.6	530.4
24	153.2	200.6	246.2	290.5	332.4	372.5	447.8	515.7
25	149.2	195.4	239.8	282.8	323.7	362.7	436.0	502.2
26	145.1	190.0	233.2	275.2	314.9	352.9	424.2	498.6

CAST IRON COLUMNS.

Safe Load in Tons of 2,000 lbs. Factor of Safety 6 to 1.

LENGTH IN FEET.	1 in. Thick.	1¼ in. Thick.	1½ in. Thick.	1¾ in. Thick.	2 in. Thick.	2¼ in. Thick.	2½ in. Thick.	3 in. Thick.
	Load.	Load.	Load.	Load.	Load.	Load.	Load.	Load.

COLUMNS 16" DIAMETER.

16	265	328.	386.	442.	497.	549.	599.	692.
17	260.	321.	378.	434.	488.	538.	587.	679.
18	255.	315.	371.	425.	478.	528.	576.	665.
19	250.	308.	363.	416.	467.	516.	563.	651.
20	244.	302.	355.	407.	458.	505.	551.	637.
21	239.	295.	348.	399.	448.	495.	540.	624.
22	234.	289.	340.	390.	438.	484.	528.	610.
23	228.	282.	332.	380.	428.	472.	515.	595.
24	223.	276.	324.	372.	418.	462.	504.	582.
25	218.	269.	316.	363.	407.	450.	491.	567.
26	212.	262.	308.	353.	397.	438.	478.	552.

COLUMNS 18" DIAMETER

	1 in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.
15	316.	461.	596.	722.	838.	945.	1043.	1131.
18	302.	439.	568.	688.	799.	901.	993.	1078.
21	286.	416.	538.	651.	756.	853.	941.	1021.
24	270.	392.	507.	615.	714.	805.	888.	963.
27	254.	369.	477.	578.	672.	756.	835.	936.
30	237.	345.	446.	540.	628.	706.	781.	847.
33	222.	322.	417.	505.	587.	660.	730.	792.
36	207.	301.	390.	472.	549.	617.	682.	740.
39	196.	281.	369.	447.	519.	584.	645.	700.
42	189.	262.	339.	410.	476.	536.	593.	643.
45	168.	244.	316.	382.	444.	500.	552.	599.

The above tables from CHENEY & HEWLETT, N. Y.

STRENGTH OF CAST IRON BEAMS.

The proper form for cast iron beams, has been obtained from the result of many experiments by Prof. Hodgkinson and others. As shown in the section, the area of bottom flange should be 6 times the area of the flange.

FORMULA.

D = Depth of beam in inches
 A = Area of bottom flange in inches
 S = Span in inches
 W = Breaking weight in tons.



Supported at both ends with } $W = \frac{25AD}{S}$
 load on centre.

Supported at both ends with } $W = \frac{50AD}{S}$
 load distributed.

If the depth = $\frac{1}{12}$ of the span } $W = A \times 4.17$ } where weight
 If the depth = $\frac{1}{10}$ of the span } $W = A \times 5$ } is distributed.

Area of top flange if the load is } $= \frac{A}{3}$
 applied on the top.

Area of top flange if the load is } $= \frac{A}{2}$
 applied on bottom flange.

Depth at the ends may equal $\frac{2D}{3}$

Safe deflection $\frac{1}{40}$ th inch for each foot of span under a test load of $\frac{1}{3}$ d of the breaking weight.

BREAKING WEIGHT OF CAST IRON GIRDERS (IN TONS DISTRIBUTED).

Span in feet.	Depth in inches.	Size of bottom flange.	Breaking weight.	Size of bottom flange.	Breaking weight.
feet	inches	inches	tons	inches	tons
10	10	$6 \times 1\frac{1}{4}$	31	$8 \times 1\frac{1}{4}$	41
15	15	$8 \times 1\frac{1}{4}$	50	$12 \times 1\frac{1}{4}$	75
20	20	$10 \times 1\frac{1}{4}$	62	$15 \times 1\frac{1}{4}$	94
25	25	$13 \times 1\frac{1}{4}$	94	19×2	158
30	30	15×2	125	22×2	183
35	35	17×2	141	25×2	208

MOLESWORTH.

To find the breaking weight of cast iron beams of section given above—load in center.

RULE.—Multiply the sectional area of bottom flange in inches by the depth of beam in inches, and divide the product by the distance between supports in inches, and 514 times the quotient = absolute strength of beam in cwts.

To find size of cast iron beam, of section given above, required to break under a given center load—having the depth given.

RULE.—Multiply given load in tons by the span in feet. Multiply constant 2.166 by total depth in inches. Divide first product by the last, and the quotient will be the area of bottom flange in square inches. This divided by 6 will = area of top flange.

The bottom flange is usually made 6 to 8 times as wide as it is thick—and top flange 3 to 6 times. Average thickness of stem $\frac{1}{14}$ to $\frac{1}{11}$ of the depth of beam.

A second rule for finding the breaking weight of cast iron beams of section given above.

RULE.—Multiply the sectional area of bottom flange in square inches by the depth of beam in inches and divide the product by the distance between supports in feet, then 2.14 times the quotient gives the breaking weight in tons.

HAZLETT.

WOODEN BEAMS.

SAFE UNIFORMLY DISTRIBUTED LOAD IN TONS OF 2000 LBS. FOR
RECTANGULAR WHITE OR YELLOW PINE BEAMS 1 INCH IN
THICKNESS.

Span in feet.	DEPTH IN INCHES.									
	5	6	7	8	9	10	11	12	13	
1	1.736	2.500	3.403	4.444	5.625	6.944	8.403	10.000	11.787	
2	0.868	1.250	1.701	2.222	2.812	3.472	4.201	5.000	5.868	
3	0.579	0.833	1.134	1.481	1.875	2.315	2.801	3.333	3.912	
4	0.434	0.625	0.851	1.111	1.406	1.738	2.101	2.500	2.934	
5	0.347	0.500	0.681	0.888	1.125	1.389	1.681	2.000	2.347	
6	0.289	0.417	0.567	0.741	0.938	1.157	1.400	1.667	1.956	
7	0.248	0.357	0.486	0.635	0.804	0.992	1.200	1.429	1.677	
8	0.217	0.312	0.425	0.555	0.708	0.868	1.050	1.250	1.467	
9	0.193	0.278	0.378	0.494	0.625	0.772	0.934	1.111	1.304	
10	0.174	0.250	0.340	0.444	0.562	0.694	0.840	1.000	1.174	
11	0.158	0.227	0.309	0.404	0.511	0.631	0.764	0.909	1.067	
12	0.145	0.208	0.284	0.370	0.469	0.579	0.700	0.833	0.978	
13	0.134	0.192	0.261	0.342	0.433	0.534	0.646	0.769	0.903	
14	0.124	0.179	0.243	0.317	0.402	0.496	0.600	0.714	0.838	
15	0.116	0.167	0.227	0.296	0.375	0.463	0.560	0.667	0.782	
16	0.109	0.156	0.213	0.278	0.352	0.434	0.525	0.625	0.734	
17	0.102	0.147	0.200	0.261	0.331	0.408	0.494	0.588	0.690	
18	0.096	0.139	0.189	0.247	0.312	0.386	0.466	0.556	0.652	
19	0.091	0.132	0.179	0.234	0.296	0.365	0.442	0.526	0.617	
20	0.087	0.125	0.170	0.222	0.281	0.347	0.420	0.500	0.587	
21	0.083	0.119	0.162	0.212	0.268	0.331	0.400	0.476	0.559	
22	0.079	0.114	0.155	0.202	0.256	0.311	0.382	0.455	0.538	
23	0.075	0.109	0.148	0.193	0.245	0.302	0.365	0.435	0.510	
24	0.072	0.104	0.142	0.185	0.234	0.289	0.350	0.417	0.489	
25	0.069	0.100	0.136	0.178	0.225	0.278	0.330	0.400	0.469	
26	.....	0.096	0.131	0.171	0.216	0.267	0.323	0.385	0.451	
27	.....	.....	0.126	0.165	0.208	0.257	0.311	0.370	0.435	
28	.....	.....	.....	0.159	0.201	0.248	0.300	0.357	0.419	
29	.....	.....	.....	.....	0.196	0.239	0.290	0.345	0.405	
30	.....	.....	.....	.....	.....	0.229	0.280	0.333	0.391	

These loads are about one-eighth the breaking load.

RULE.—To find the safe uniformly distributed load in tons for white or yellow pine beams, multiply the number given in the above table by the thickness of the beam in inches. For beams of other wood multiply also by the following numbers :

White Oak.
1.45

Hemlock.
.95

White Cedar.
.63

Spruce.
.86

SAFE LOAD IN TONS OF 2000 LBS., FOR RECTANGULAR WOODEN COLUMNS.

FIXED AT BOTH ENDS BY BRACES OR OTHERWISE.

RULE.—Divide the length of the column by the least diameter both in inches ; multiply the number in column headed C corresponding to the quotient $\frac{L}{D}$ so found by the width and by the thickness of the column in inches.

If the column is not secured by braces or otherwise, but has merely a bearing on its own cross section, the load should not be more than half that here given.

This table is calculated for dry oak. For pine, about three-quarters of the load allowed may be applied. For wet timber *one-half*.

EXAMPLE —What is the safe load for an oak pillar fixed at both ends 20 feet long, 8 inches by 10 inches.

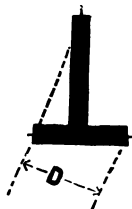
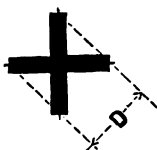
$$\frac{L}{D} = \frac{240}{8} = 30, \text{ for which } C = .086 ;$$

$$.086 \times 8 \times 10 = 6.88 \text{ tons.}$$

$\frac{L}{D}$	C	$\frac{L}{D}$	C	$\frac{L}{D}$	C
1	0.399	18	0.174	35	0.067
2	0.394	19	0.163	36	0.064
3	0.386	20	0.154	37	0.061
4	0.376	21	0.144	38	0.059
5	0.363	22	0.136	39	0.056
6	0.349	23	0.128	40	0.054
7	0.334	24	0.121	41	0.051
8	0.319	25	0.114	42	0.049
9	0.302	26	0.108	43	0.047
10	0.285	27	0.102	44	0.045
11	0.269	28	0.096	45	0.044
12	0.254	29	0.091	46	0.042
13	0.238	30	0.086	47	0.040
14	0.224	31	0.082	48	0.039
15	0.210	32	0.078	49	0.037
16	0.197	33	0.074	50	0.036
17	0.185	34	0.071		

This table is calculated by Gordon's formula (Rankin's Civil Eng. p. 237) taking 8000 lbs. per square inch as the crushing load of oak, and assuming $\frac{1}{10}$ the breaking weight for the safe load.

SAFE LOAD IN TONS OF 2000 LBS. FOR CAST AND
WROUGHT IRON COLUMNS OF VARIOUS
SECTIONS.



HAVING FACED CAPITALS AND BASES.

An approximate rule for determining the safe load of columns of any form of cross-section, is as follows:

RULE.—Divide the length of the column by the least diameter D measured, as shown by the accompanying cuts, both in inches, multiply the number in column headed C of the table on the next page, corresponding to the quotient $\frac{L}{D}$, so found by the area of cross-section of the column in square inches.

If the columns are not provided with faced capitals and bases, the loads so found are to be divided by the number in column headed "Rounded Ends," corresponding to the quotient $\frac{L}{D}$.

EXAMPLE.—What safe load can be borne by a hollow rectangular cast-iron column 12 inches wide by 12 inches deep, and 15 feet long, the thickness being 1 inch, and the column provided with faced capital and base?

Here, $D = 12$; $L = 180$ $\frac{L}{D} = 15$, opposite which number in the column for cast iron we find 8.14. The area of cross-section of the column is 82 square inches, which multiplied by 8.14 = 100.48 tons the safe load.

If the column were not provided with faced capital and base, it would be necessary to divide this load by the number 2.59, found in column headed "Rounded Ends," and the safe load thus obtained would be 38.8 tons.

This table is calculated by Gordon's formula, taking 8000 lbs. per square inch as the safe load for a short column of wrought iron, and $6\frac{1}{2}$ tons for cast iron. The quantities are respectively $\frac{1}{4}$ and $\frac{1}{2}$ of the breaking load.

The stiffness of a column is greater the further the metal in it is removed from the center in every direction ; hence, the hollow square is the best form. and hollow cylinder next best. Other forms similar to those represented have about the same stiffness in proportion to the amount of metal in them as a solid square section, and the figures given in the table for wrought iron are those which would be exact for such a section. Those given for cast iron are correct for hollow cylinders, and therefore are small for long columns of a hollow rectangular form, and somewhat in excess for those of other shapes.

For very short columns, the form of section makes but little difference.

L — D	CAST IRON.		WROUGHT IRON		L — D	CAST IRON.		WROUGHT IRON.	
	C	Rounded ends.	C	Rounded ends.		C	Rounded ends.	C	Rounded ends.
7	6.28	1.17	3.94	1.04	41	2.15	3.08	2.57	2.07
8	6.17	1.22	3.92	1.06	42	2.08	3.06	2.52	2.10
9	6.05	1.28	3.89	1.08	43	2.01	3.09	2.48	2.13
10	5.93	1.33	3.87	1.10	44	1.95	3.11	2.43	2.17
11	5.79	1.39	3.85	1.12	45	1.89	3.14	2.39	2.20
12	5.65	1.46	3.82	1.15	46	1.83	3.17	2.35	2.23
13	5.50	1.52	3.79	1.17	47	1.77	3.20	2.30	2.27
14	5.35	1.60	3.75	1.19	48	1.72	3.23	2.26	2.30
15	5.20	1.68	3.72	1.21	49	1.67	3.25	2.22	2.33
16	5.05	1.75	3.69	1.23	50	1.62	3.27	2.18	2.36
17	4.90	1.82	3.65	1.26	51	1.57	3.30	2.14	2.39
18	4.75	1.88	3.61	1.29	52	1.52	3.32	2.11	2.42
19	4.59	1.94	3.57	1.32	53	1.48	3.33	2.07	2.45
20	4.44	2.00	3.53	1.35	54	1.44	3.35	2.03	2.48
21	4.30	2.07	3.49	1.38	55	1.39	3.37	1.99	2.51
22	4.15	2.13	3.44	1.42	56	1.35	3.39	1.95	2.53
23	4.01	2.20	3.40	1.45	57	1.32	3.41	1.92	2.56
24	3.88	2.27	3.36	1.49	58	1.28	3.42	1.89	2.59
25	3.74	2.33	3.31	1.52	59	1.25	3.44	1.85	2.61
26	3.61	2.38	3.26	1.56	60	1.21	3.45	1.82	2.64
27	3.49	2.44	3.22	1.59	61	1.18	3.47	1.79	2.66
28	3.37	2.49	3.17	1.63	62	1.15	3.48	1.76	2.68
29	3.25	2.54	3.12	1.66	63	1.12	3.50	1.73	2.71
30	3.14	2.59	3.08	1.69	64	1.09	3.51	1.69	2.73
31	3.03	2.64	3.03	1.73	65	1.06	3.52	1.66	2.75
32	2.92	2.69	2.99	1.76	66	1.03	3.53	1.63	2.78
33	2.82	2.74	2.94	1.80	67	1.01	3.55	1.60	2.80
34	2.73	2.78	2.89	1.83	68	.98	3.56	1.57	2.82
35	2.63	2.82	2.84	1.86	69	.96	3.57	1.54	2.84
36	2.54	2.86	2.79	1.90	70	.94	3.58	1.52	2.86
37	2.46	2.90	2.75	1.93	80	.74	3.67	1.28	3.04
38	2.38	2.93	2.70	1.97	90	.60	3.74	1.08	3.19
39	2.30	2.97	2.65	2.00	100	.49	3.78	.92	3.30
40	2.22	3.00	2.61	2.04	....	.....	.....	.....	.....

From Hand Book of N. J. Steel and Iron Co., Trenton, N. J.

WOODEN WATER TANKS.

CONVENIENT SIZES AND CONTENTS.

Dia. Feet.	Depth Ft.	Gallons.	Dia. Ft.	Depth Ft.	Gallons.
8	6	2256	13	10	9928
9	6	2855	14	10	11514
10	7	4112	15	10	13218
11	8	5687	15	12	15862
12	8	6768	16	10	15039
12	10	8460	16	12	18047

Circular water tanks of wood if properly constructed, are very durable and for a gas works of medium size, will answer every purpose, for many years. A tank should always be made at least 15 per cent. larger than actually required—to allow for leakage, stoppage of pumps, repairs, &c.

Pine or oak wood can be used, but pine is good enough and is the cheapest and easiest worked.

The staves should be from $2\frac{1}{2}$ to 4 inches thick, and the bottom about 8 ins. thick.

Whether the tank is supported on wooden or iron beams or on brick walls, the bottom planks should have a solid bearing.

The weight of water per gallon 8.338, lbs multiplied by the number of gallons, will of course give the weight—to which must be added the weight of the tank itself.

Great care must be taken in having the tank strongly hooped, and also in having the hoops of sufficient strength and strongly riveted.

The largest size above given, will require at least 10 hoops of 3 by $\frac{1}{2}$ inch iron, with $\frac{1}{4}$ inch rivets.

The hoops should be placed closer together at the bottom than at the top, and the two bottom hoops, should be not more than 3 ins. apart.

The tank should be made slightly smaller in dia. at the top than at the bottom to allow the hoops to be driven tight.

The overflow pipe should be of the same size as the supply pipe.

The discharge pipe should be covered with a brass strainer on the inside of tank.

A telltale can be arranged in various ways ; perhaps the best is a small lead pipe opening into a sink in the engine or pump room, having its opening from tank just below the level of overflow pipe.

The tank, particularly the iron hoops should be kept painted

TO COMPUTE THE CAPACITY OF CIRCULAR TANKS.

RULE—The diameter in feet, squared and multiplied by .7854 — the area in square feet.

The area multiplied by the depth — the cubic contents in cubic feet.

The contents in cubic feet multiplied by 7.48 (the number of gallons per cub. ft.) = capacity in gallons.

If the tank is smaller at the top than at the bottom, the diameter must be taken at a point midway between top and bottom.

BOLTS FOR IRON ROOFS, &c.

Take $\frac{7}{8}$ of the diameter of the rod, for the diameter of the bolt for a *double shear* and $\frac{2}{3}$ of the diameter of the rod, for the diameter of the bolt for a *single shear*.

Diameter of the Rod.		Diameter of the bolt. Double shear.		Diameter of the bolt. Single shear.
$\frac{1}{4}$ inch	.....	$\frac{3}{16}$ inch	.....	$\frac{5}{16}$ inch
$\frac{3}{8}$ "	.....	$\frac{5}{16}$ "	.....	$\frac{7}{16}$ "
$\frac{1}{2}$ "	.....	$\frac{7}{16}$ "	.....	$\frac{9}{16}$ "
$\frac{5}{8}$ "	.....	$\frac{9}{16}$ "	.....	$\frac{11}{16}$ "
$\frac{3}{4}$ "	.....	$\frac{5}{8}$ "	.....	$\frac{13}{16}$ "
$\frac{7}{8}$ "	.....	$\frac{3}{4}$ "	.....	1 "
1 "	.....	$\frac{7}{8}$ "	.....	$1\frac{1}{8}$ "
$1\frac{1}{8}$ "	.....	1 "	.....	$1\frac{1}{4}$ "
$1\frac{1}{4}$ "	.....	$1\frac{1}{8}$ "	.....	$1\frac{3}{8}$ "

$1\frac{3}{8}$ inch	.....	$1\frac{5}{8}$ inch	.....	$1\frac{1}{2}$ inch
$1\frac{1}{2}$ "	.....	$1\frac{5}{8}$ "	.....	$1\frac{5}{8}$ "
$1\frac{5}{8}$ "	.....	$1\frac{7}{8}$ "	.....	$1\frac{3}{4}$ "
$1\frac{3}{4}$ "	.....	$1\frac{1}{2}$ "	.....	2 "
$1\frac{7}{8}$ "	.....	$1\frac{5}{8}$ "	.....	$2\frac{1}{8}$ "
2 "	.....	$1\frac{3}{4}$ "	.....	$2\frac{1}{4}$ "
$2\frac{1}{8}$ "	.....	$1\frac{7}{8}$ "	.....	$2\frac{3}{8}$ "
$2\frac{1}{4}$ "	.....	2 "	.....	$2\frac{1}{2}$ "
$2\frac{3}{8}$ "	.....	$2\frac{1}{8}$ "	.....	$2\frac{5}{8}$ "
$2\frac{1}{2}$ "	.....	$2\frac{1}{4}$ "	.....	$2\frac{3}{4}$ "

Pins for bridges, and similar constructions that are subject to a vibrating motion, and consequently to a wearing motion should be made larger in diameter than those given in the table.

For the metal around the eye take one-half the area of the rod and add one-third to it.

STREET MAINS.

The important item of "Gas unaccounted for" which appears in the accounts of all gas managers, is for the most part made up of condensation and leakage; this latter being probably the greater part. It is due principally to defective joints, and worn out service pipes. The condition of the soil, shown by color and smell when a trench is opened in a city street in which gas mains have been laid for any length of time, will prove that the leakage is continually going on. The death of shade trees can be often traced to this source.

Probably no part of the plant of a gas works, requires greater care than the street mains, and services, and generally no part receives less attention, except when a leak becomes too palpable, and its very offensiveness demands and gains for it immediate attention.

To prevent as much as possible this continual loss, the pipes should be tested under water pressure, when made, and to secure an even thickness of metal, they should be cast vertically in dry sand. The pipes should also be carefully examined on the ground by sounding with a hammer, the tone indicating any unsoundness, of a serious character. In a growing district no pipes of less than 4 ins. dia. should be laid, and 3 inch pipes should be laid sparingly, in any place. In contracting for pipes, 4 per cent. above or below the standard weight is usually allowed.

Pipes are cast vertically, and care is generally taken to center the core, but it sometimes happens that the core is out of line and the casting is of uneven thickness; too thick on one side and too thin on the other. This is a frequent cause of breakage and leakage. It is a fault very hard to detect before breaking. It can sometimes be discovered where the difference of thickness is great, by rolling the pipe on perfectly level skids, and balancing the pipe on every inch of its circumference, which can be done by rolling it very slowly, on the level skids.

Pipes made by different manufacturers, differ sometimes in the size of the bead on the spigot end, and in the inner diameter of hub, so that the spigot of one make of pipe will not enter the hub of another. The remedy for this is either to order pipe from one manufacturer only, or to have the pipes made strictly as per description in contract, and reject all that do not come up to the requirements in every particular.

For city streets and places where the traffic is heavy, pipes of greater weight should be laid, than in places where the traffic is light. In country towns, they can generally be laid outside the limits of travel on the streets, and they are sometimes laid inside of the curb line.

The formula for calculating the weight of cast iron pipes is

$$W = 2.45 (D^2 - d^2)$$

Where D = outside diameter of pipe in inches

d = inside " " " " "

W = weight of a lineal foot of pipe in lbs.

Pipes laid in city streets, where the traffic is heavy, should be thicker than those laid in retired places, and in places where they can be laid under the side walk. The depth of socket for sizes up to 20 inches dia. should be 4 ins., above that they should be from 4½ to 5 inches.

Joints for mains are mostly made with lead and yarn, some however are made with cement. In turning corners and large curves special castings should always be used. In laying mains in a new district 10 per cent. of the whole will be special castings. Bends, tees, sleeves, reducers, branches, &c.

Large mains should be laid on a bed of concrete, of proper thickness or on brick piers, and all mains should be laid on regular grades, with the elevations and distance from curb recorded at each change of grade and street corner. Where a street or avenue

is extra wide, a double line of pipe is found to be the most economical, but these lines should be connected at short intervals to insure a good distribution, and uniform pressure.

In making joints with lead, the socket is filled about half full of yarn, caulked down evenly all around. A roll of clay is then placed against the hub, with an opening, through which the molten lead is poured, filling the socket, after which it is set up with a caulking chisel, making a tight joint. The custom of coating cast iron pipes with hot coal tar, while possibly good for the outside, is not good for the inside, as it is the cause eventually of leaky joints, as the coating is dissolved by the gas, and collects in the drips and joints.

TABLE.

GIVING THE WEIGHT OF LEAD IN POUNDS REQUIRED FOR JOINT-
ING CAST IRON MAINS.

Diameter of pipe in inches.	Depth of lead in inches.	Weight of lead in pounds.	Diameter of pipe in inches.	Depth of lead in inches.	Weight of lead in pounds.
3	1 $\frac{5}{8}$	2 $\frac{3}{4}$	12	2 $\frac{3}{8}$	18 $\frac{1}{2}$
4	1 $\frac{3}{4}$	4	14	2 $\frac{3}{8}$	23 $\frac{1}{2}$
5	1 $\frac{7}{8}$	5 $\frac{1}{2}$	16	2 $\frac{1}{2}$	28 $\frac{1}{2}$
6	2	7	18	2 $\frac{3}{8}$	32 $\frac{1}{2}$
7	2	8 $\frac{3}{4}$	20	2 $\frac{3}{8}$	35 $\frac{1}{2}$
8	2 $\frac{1}{8}$	10 $\frac{1}{2}$	24	3	48
10	2 $\frac{1}{4}$	14 $\frac{1}{2}$			

The depth at which mains should be laid, will vary in different places, but they should be entirely below the frost line, and where the traffic over them is heavy, they should be laid still deeper. The bottom of trench should be even and firm, and the dirt should be rammed down around and above the pipes.

For small sizes of pipes, it is sometimes advantageous to join two lengths together before laying them in the trench.

Mains laid in ashes, or ground made up of rubbish, or refuse of various kinds, should be covered all around with good soil, well rammed down. Drips of sufficient capacity with pumping tubes should be placed at all low points, to receive condensation.

FORMULA FOR GAS DISTRIBUTION—BY LEWIS THOMPSON.

TO ACCOMMODATE PRESSURE OF GAS TO DEMAND.

FORMULA.—The present quantity of gas is to the desired quantity, as the square root of the present pressure, is to square root of the pressure required.

EXAMPLE.—The quantity of gas now delivered is 322,000 cubic feet per hour, with $1\frac{1}{2}$ inch pressure ; it is required to deliver by the same pipe 416,000 cubic feet per hour—what pressure must be used?

RULE.—Divide the required quantity by the present quantity, and multiply the product by the square root of the pressure, this product will be the square root of the required pressure. which squared gives the required pressure—which in Barlow's tables is 2.5 inches—thus :

$$\begin{aligned} \frac{416,000}{322,000} &= 1.292 \times 1.225 \text{ (the square root of } 1\frac{1}{2}) = 1.582 \times \\ 1.582 &= 2.502 \end{aligned}$$

To find the quantity of gas that will be passed by change of pressure from one pressure to another.

FORMULA.—The square root of previous pressure, is to square root of altered pressure, as the previous quantity of gas, is to the gas that will pass by altered pressure.

EXAMPLE —Under half inch pressure, gas was passing at the rate of 1145 cubic feet per hour, how much gas will pass if the pressure is increased to 2 inches?

RULE.—Multiply the lesser quantity of gas by the square root of the greater pressure and divide this product by the square root of the lesser pressure—thus :

$$1145 \times 4.472 = \frac{5120.44}{.2236} = 2290 \text{ cubic feet.}$$

To ascertain the flow of gas by tubes of different diameters, the pressure remaining unchanged.

From a small to a large diameter. Rule.—Divide the large diameter by the small diameter, and multiply the square of the product, by the square root of the large diameter, and divide by the square root of the small diameter, then multiply the result by the quantity of gas passing through the smaller tubes—which will furnish the amount of gas that will pass by the larger tubes.

EXAMPLE.—A tube 18 ins. dia. is passing under 2 inches pressure, at a distance of 3000 yards, 75.700 cubic ft. of gas—how much will a tube of 36 ins. dia. pass under the same circumstances?

$$\frac{36}{18} = 2 \text{ and } 2^2 = 4 \times 6 \text{ (sq. root of large dia.)} = \frac{24}{4.243} = 5.656.$$

(sq. root of small dia.)
and 5.656×75.700 (the quantity of gas passing) = 428,159 cubic feet.

By reversing this rule we can go from large to small diameters.

The pressure and distance being given, to know the amount of gas that will be delivered at any other distance,

RULE.—The quantities are in the inverse ratio of the square root of the distance.

EXAMPLE 1.—A main under one inch pressure is delivering 530,000 cubic feet per hour at a distance of 1000 yards; how much will it deliver under the same pressure at 4000 yards?

$$\frac{530,000 \times \sqrt{1000}}{\sqrt{4000}} = 265,000.$$

EXAMPLE 2.—A certain main delivers 530,000 cubic ft. per hour at 1000 yds—how much under the same pressure will it deliver at a distance of 120 miles?

$$\frac{530,000 \times 31.62}{459.56} = 36,471 \text{ cubic feet per hour.}$$

The quantity of gas delivered of the specific gravity of .400 being given in the preceding Tables, to ascertain the quantity that will be delivered of any other specific gravity.

RULE.—Multiply the quantity of gas delivered, by the square root of its specific gravity, and divide by the square root of the specific gravity of the gas in question.

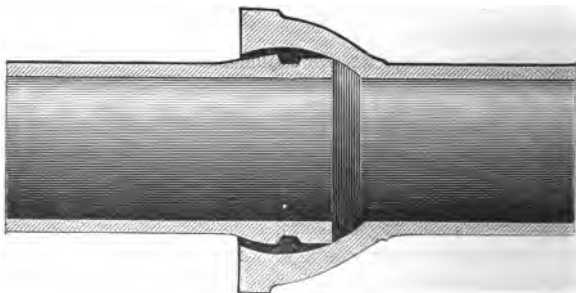
EXAMPLE.—A main 1500 yds. long is supplying 17,400 cubic ft. of gas of .400 specific gravity, with a pressure of one inch; how much will the main deliver under the same length and pressure, the gas having a specific gravity of .600?

$$\text{Sq. root of .400} = .6325 \times 17,400 = \frac{11,055,000}{7746} = 14,208 \text{ ft.}$$

GAS MAINS UNDER WATER.

As it often happens that gas mains have to be laid under the water of rivers, harbors, or canals, great trouble would be found, in laying any pipe having a rigid joint. To overcome this difficulty, the ball and socket joint is used. The illustration shows a section of the joint used by Mr. J. F. Ward of Jersey city, who has made this kind of work a speciality.

The spigot and socket end are both turned, and the joints are filled with lead and caulked from a float, the pipe being paid out like a chain, as each joint is made.



The peculiar shape of the spigot end makes it hold the lead firmly, and still allows a movement of more than 12 degrees in all directions, enabling the pipes to adjust themselves to the shape of the bottom with ease and safety.

Pipes from 6 inch to 36 inches diameter have been laid with this joint, in lengths from 900 to 4000 feet.

TABLE.

SHOWING THE DIAMETER OF PIPES IN DECIMALS OF AN INCH,
TO SUPPLY LIGHTS AT CERTAIN DISTANCES FROM THE MAIN.

Distance of Light from Mains.	Number of Lights each burning 5 feet per hour with a pressure of one inch.						
In Feet.	3	5	10	15	20	25	30
5	.1545	.1888	.2491	.2942	.3287	.3594	.3882
10	.1768	.2169	.2861	.3366	.3776	.4129	.4441
15	.1917	.2352	.3103	.3650	.4095	.4478	.4816
20	.2081	.2491	.3287	.3866	.4338	.4743	.5102
30	.2202	.2702	.3564	.4193	.4704	.5143	.5533
40	.2333	.2862	.3776	.4441	.4983	.5448	.5860
50	.2439	.2992	.3948	.4644	.5210	.5697	.6128
60	.2530	.3102	.4095	.4816	.5404	.5908	.6355
70	.2609	.3201	.4223	.4967	.5573	.6093	.6554
80	.2680	.3287	.4337	.5125	.5724	.6258	.6701
90	.2743	.3366	.4440	.5223	.5860	.6407	.6892
100	.2802	.3437	.4535	.5334	.5985	.6544	.7034
150	.3039	.3728	.4918	.5705	.6490	.7097	.7634
200	.3219	.3948	.5209	.6128	.6875	.7517	.8086
250	.3366	.4129	.5447	.6407	.7189	.7860	.8455
300	.3490	.4282	.5650	.6645	.7456	.8152	.8769

Distance of Lights from Main.	Number of Lights, each burning 5 feet per Hour with a pressure of one Inch.					
In Feet.	40	50	100	150	200	300
5	.4338	.4743	.6257	.7391	.8258	.9752
10	.4983	.5448	.7188	.8377	.9486	1.1157
15	.5404	.5908	.7795	.9169	1.0288	1.2099
20	.5724	.6258	.8257	.9712	1.0897	1.2815
30	.6207	.6787	.8954	1.0533	1.1817	1.3898
40	.6575	.7189	.9484	1.1156	1.2517	1.4721
50	.6875	.7517	.9917	1.1665	1.3089	1.5393
60	.7130	.7792	1.0286	1.2099	1.3574	1.5965
70	.7354	.8040	1.0608	1.2478	1.4000	1.6464
80	.7553	.8258	1.0895	1.2874	1.4378	1.6910
90	.7733	.8455	1.1155	1.3121	1.4721	1.7313
100	.7897	.8635	1.1394	1.3400	1.5035	1.7681
150	.8564	.9368	1.2356	1.4532	1.6305	1.9175
200	.9072	.9919	1.3088	1.5393	1.7270	2.0311
250	.9486	1.0371	1.3685	1.6095	1.8058	2.1238
300	.9838	1.0757	1.4197	1.6693	1.8729	2.2540

EFFECTS OF DIFFERENT SOILS ON CAST IRON PIPES.

Different kinds of soil affect cast iron mains in various ways. Clay preserves them in a remarkable manner. When laid in a saline sandy soil, a coat of sesqui-oxide of iron is formed on the exterior which increases in thickness, corresponding to the time it has been buried. Pipes laid in made ground, with ashes, &c., are soon pierced with small holes, and destroyed.

CAST IRON PIPES FOR GAS MAINS.

SHOWING THICKNESS OF METAL, AND WEIGHT PER 12 FEET
LENGTH INCLUDING HUB.

Dia- meter ins.	LIGHT.		HEAVY.		Dia- meter ins.	LIGHT.		HEAVY.	
	Thi'k- ness ins.	Weight Lbs.	Thi'k- ness ins.	Weight Lbs.		Thi'k- ness ins.	Weight Lbs.	Thi'k- ness ins.	Wt. Lbs.
3	.31	132	.38	167	18	.63	1500	.63	1533
4	.38	186	.40	230	20	.63	1680	.66	1788
5	.40	240	.42	295	24	.72	2220	.73	2359
6	.40	300	.43	364	30	.84	3300	.83	3330
8	.44	456	.46	513	36	.95	4500	.93	4444
10	.44	600	.50	685	40	1.05	5400	.99	5275
12	.46	696	.53	870	42	1.10	5700	1.03	5721
14	.53	960	.56	1074	48	1.04	6600	1.13	7150
16	.56	1200	.60	1293					

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS, &c.

BY THE LATE T. G. BARLOW, ESQ.

DISCHARGE OF GAS IN CUBIC FEET PER HOUR, THROUGH PIPES OF VARIOUS DIAMETERS AND LENGTHS, AT DIFFERENT PRESSURES. THE SPECIFIC GRAVITY OF THE GAS ESTIMATED AT .400 AIR BEING 1.000.

DIAMETER OF PIPE, .5 INCH.							
Length in yards.....	10	20	30	50	75	100	150
Quantity delivered with 0.1 inch pressure.	37.7	26.7	21.7	16.8	13.8	11.9	9.7
“ “ 0.2	53.4	37.7	30.6	23.8	19.5	16.8	13.8
“ “ 0.3	65.2	46.3	37.7	29.1	23.8	20.7	16.8
“ “ 0.4	.....	.....	.....	33.7	27.5	23.8	19.5
“ “ 0.5	.....	.....	.....	.....	...	26.7	21.7
DIAMETER OF PIPE, .75 INCH.							
Length in yards.....	10	20	30	50	75	100	150
Quantity delivered with 0.1 inch pressure.....	104.3	73.8	60.0	46.6	37.9	32.9	26.9
“ “ 0.2	147.5	104.3	84.9	65.8	53.7	46.6	37.9
“ “ 0.3	.....	.....	104.3	80.9	65.8	57.0	46.6
“ “ 0.4	.....	.....	.....	93.2	75.9	65.8	52.8
“ “ 0.5	.....	.....	.....	.....	.....	73.8	60.0
DIAMETER OF PIPE, 1 INCH.							
Length in yards.....	10	20	30	50	75	100	150
Quantity delivered with 0.1 inch pressure.....	214	151	124	95	78	67	55
“ “ 0.2	302	214	175	135	110	95	78
“ “ 0.3	.....	.....	214	165	135	117	95
“ “ 0.4	.....	.....	.....	190	156	135	110
“ “ 0.5	.....	.....	.....	.....	.....	151	123

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS, &c., (Continued)

DIAMETER OF PIPE, 1.25 INCH.									
Length in yards.....	25	50	75	100	150	200	300		
Quantity delivered with 0.1 inch pressure.....	236	167	137	118	96	84	68		
" " 0.2 ".....	333	236	192	167	137	118	196		
" " 0.3 ".....	.....	289	236	205	167	144	118		
" " 0.4 ".....	.....	.....	.....	236	192	167	137		
" " 0.5 ".....	.....	.....	.....	.....	.....	187	152		
DIAMETER OF PIPE, 1.5 INCH.									
Length in yards.....	25	50	75	100	150	200	300		
Quantity delivered with 0.1 inch pressure.....	374	264	215	187	152	132	107		
" " 0.2 ".....	528	374	304	264	215	187	152		
" " 0.3 ".....	.....	458	374	322	264	229	187		
" " 0.4 ".....	.....	.....	.....	374	304	264	215		
" " 0.5 ".....	.....	.....	.....	.....	.....	295	239		
DIAMETER OF PIPE, 2 INCHES.									
Length in yards.....	50	75	100	150	200	300	500		
Quantity delivered with 0.1 inch pressure.....	540	441	381	311	270	220	170		
" " 0.2 ".....	763	633	540	441	381	311	241		
" " 0.3 ".....	.....	763	665	540	468	331	296		
" " 0.4 ".....	.....	.....	623	540	441	341	241		
" " 0.5 ".....	.....	.....	.....	.....	.....	492	381		
DIAMETER OF PIPE, 2.5 INCHES.									
Length in yards.....	50	75	100	150	200	300	500		
Quantity delivered with 0.1 inch pressure.....	943	770	667	545	471	335	298		
" " 0.2 ".....	1335	1090	943	770	667	545	421		

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS &c., (Continued.)

DIAMETER OF PIPE, 12 INCHES.									
Length in yards.	500	750	1000	1250	1500	1750	2000		
Quantity delivered with 0.3 inch pressure.	26,100	21,400	19,500	16,500	15,100	13,880	13,050		
" " 0.4	30,200	24,600	21,400	19,100	17,400	16,100	15,100		
" " 0.5	33,600	27,500	23,800	21,400	19,440	18,050	16,800		
" " 0.6	....	30,200	26,100	23,300	21,400	19,800	19,500		
" " 0.8	....	....	30,200	26,900	24,600	22,700	21,400		
" " 1.0	....	....	....	30,200	27,500	25,450	23,800		
" " 1.5	....	....	....	....	33,600	31,250	29,250		
" " 2.0	....	....	....	....	....	36,100	33,600		
DIAMETER OF PIPE 14 INCHES.									
Length in yards.	500	750	1000	1250	1500	1750	2000		
Quantity delivered with 0.1 inch pressure.	22,100	18,100	15,600	13,950	12,750	11,800	11,050		
" " 0.2	31,200	25,500	22,100	19,800	18,100	16,700	15,600		
" " 0.3	38,400	31,200	27,100	24,250	22,100	20,500	19,200		
" " 0.4	44,200	36,200	31,200	27,900	25,500	23,600	22,100		
" " 0.5	49,400	40,400	35,000	31,200	28,500	26,460	24,700		
" " 0.6	....	44,200	38,400	34,300	31,200	28,900	27,100		
" " 0.8	....	....	44,200	39,600	36,200	33,400	31,200		
" " 1.0	....	....	....	44,200	40,400	37,300	35,000		
" " 1.5	....	....	....	....	49,400	45,700	42,600		
" " 2.0	....	....	....	....	....	52,920	49,400		
DIAMETER OF PIPE, 15 INCHES.									
Length in yards.	500	750	1000	1250	1500	1750	2000		
Quantity delivered with 0.1 inch pressure.	26,300	21,400	18,600	16,600	15,200	14,000	13,150		
" " 0.2	37,200	30,400	26,300	23,500	21,400	19,900	18,600		

'TABLE OF THE DISCHARGE OF HIGH MAINS, &c., (Continued.)

DIAMETER OF PIPE, 15 INCHES.									
Length in yards.....	0.3 inch pressure.....	500	750	1000	1250	1500	1750	2000	
Quantity delivered with	0.4	45,500	37,200	32,250	28,750	26,300	24,300	22,750	
"	"	52,600	42,800	37,200	33,200	30,400	28,000	26,300	
"	0.5	58,700	48,000	41,600	37,200	34,000	31,400	29,350	
"	0.6	.....	52,600	45,500	40,700	37,200	34,450	32,250	
"	0.8	.....	.....	52,600	47,000	42,800	39,800	37,200	
"	1.0	.....	.....	.....	52,600	48,000	44,400	41,600	
"	1.5	.....	.....	.....	.....	58,700	54,300	50,800	
"	2.0	.....	.....	.....	.....	.....	.....	58,700	
DIAMETER OF PIPE, 16 INCHES.									
Length in yards.....	0.1 inch pressure.....	500	750	1000	1250	1500	1750	2000	
Quantity delivered with	0.2	31,000	25,250	21,850	19,550	17,850	16,550	15,500	
"	"	43,700	35,700	31,000	27,700	25,250	22,400	21,850	
"	0.3	53,600	43,700	38,100	34,000	31,000	28,700	26,800	
"	0.4	62,000	55,000	43,700	39,100	35,700	33,100	31,000	
"	0.5	69,120	56,600	49,000	43,700	39,900	37,150	34,560	
"	0.6	.....	62,000	58,600	47,900	43,700	38,100	34,560	
"	0.8	.....	.....	62,000	55,400	50,500	46,800	43,700	
"	1.0	.....	.....	.....	62,000	56,600	52,400	49,000	
"	1.5	.....	.....	.....	.....	69,120	63,900	60,100	
"	2.0	.....	.....	.....	.....	.....	74,300	69,120	
DIAMETER OF PIPE, 18 INCHES.									
Length in yards.....	0.1 inch pressure.....	500	750	1000	1500	2000	2500	3000	
Quantity delivered with	0.2	41,400	33,800	29,400	23,900	20,700	18,400	16,900	
"	"	58,800	47,800	41,400	33,800	29,400	26,200	23,900	

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS &c., (Continued.)

DIAMETER OF PIPE, 18 INCHES.										
Length in yards.		500	750	1000	1500	2000	2500	3000		
Quantity delivered with 0.3 inch pressure.		71,800	58,800	50,800	41,400	35,900	32,100	29,400		
"	0.4	82,800	67,600	58,800	47,800	41,400	36,800	33,800		
"	0.5	92,800	75,700	65,600	53,500	46,800	41,400	37,850		
"	0.6	.....	82,800	71,800	58,800	50,800	45,400	41,400		
"	0.8	.....	.....	82,800	67,600	58,800	52,300	47,500		
"	1.0	.....	.....	.....	75,700	65,600	58,800	53,500		
"	1.5	.....	.....	.....	.....	80,000	71,800	65,600		
"	2.0	.....	.....	.....	.....	.....	82,800	75,700		
"	2.5	.....	.....	.....	.....	.....	.....	84,500		
DIAMETER OF PIPE, 20 INCHES.										
Length in yards.		500	750	1000	1500	2000	2500	3000		
Quantity delivered with 0.1 inch pressure.		54,000	44,000	38,250	31,200	27,000	24,200	22,000		
"	0.2	76,500	62,400	54,000	44,000	38,250	34,200	31,200		
"	0.3	93,500	76,500	66,100	54,000	46,750	41,800	38,250		
"	0.4	108,000	88,000	76,500	62,400	54,000	48,400	44,000		
"	0.5	120,500	98,800	85,300	69,800	62,250	54,000	49,400		
"	0.6	.....	108,000	93,500	76,500	66,100	59,100	54,000		
"	0.8	.....	.....	108,000	88,000	76,500	68,400	62,400		
"	1.0	.....	.....	.....	98,800	85,300	76,500	69,800		
"	1.5	.....	.....	.....	.....	102,800	93,500	85,300		
"	2.0	.....	.....	.....	.....	.....	108,000	98,800		
"	2.5	.....	.....	.....	.....	.....	.....	110,200		

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS &c, (Continued)

DIAMETER OF PIPE, 22 INCHES.									
Length in yards.	500	750	1000	1500	2000	2500	3000		
Quantity delivered with 0.1 inch pressure.	68,600	56,000	48,400	39,600	34,300	30,700	28,000		
" " 0.2	96,800	79,200	68,600	56,000	48,400	43,400	39,600		
" " 0.3	118,800	96,800	84,000	68,600	59,400	53,300	48,400		
" " 0.4	137,200	112,000	96,800	79,200	68,600	61,400	56,000		
" " 0.5	153,500	122,500	108,200	88,600	76,800	68,400	61,200		
" " 0.6	....	137,200	118,800	96,800	84,000	75,000	68,600		
" " 0.8	....	....	137,200	112,000	96,800	86,500	79,200		
" " 1.0	....	....	....	122,500	108,200	96,800	88,600		
" " 1.5	....	....	....	....	132,000	118,800	108,200		
" " 2.0	....	....	....	....	....	137,200	122,500		
" " 2.5	....	....	....	....	....	....	140,000		
DIAMETER OF PIPE, 24 INCHES.									
Length in yards.	500	750	1000	1500	2000	2500	3000		
Quantity delivered with 0.1 inch pressure.	84,000	68,600	59,500	48,500	42,000	37,500	34,300		
" " 0.2	119,000	97,000	84,000	68,600	59,500	53,400	48,500		
" " 0.3	145,500	119,000	103,000	84,000	72,700	65,200	59,500		
" " 0.4	168,000	137,200	119,000	97,000	84,000	75,000	68,600		
" " 0.5	187,500	155,000	135,600	108,600	93,800	84,000	77,500		
" " 0.6	....	168,000	145,000	119,000	103,000	92,000	84,000		
" " 0.8	....	....	168,000	137,200	119,000	106,000	97,000		
" " 1.0	....	....	....	155,000	135,600	119,000	108,600		
" " 1.5	....	....	....	....	163,000	145,500	135,600		
" " 2.0	....	....	....	....	....	168,000	155,000		
" " 2.5	....	....	....	....	....	....	172,000		

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS &c., (Continued.)

DIAMETER OF PIPE, 26 INCHES.										
Length in yards.....		750	1000	1500	2000	2500	3000	4000		
Quantity delivered with 0.1 inch pressure.....	0.2	85,000	73,500	60,000	52,000	46,500	42,500	36,750		
" " 0.2		120,000	104,000	85,000	73,500	65,800	60,000	52,000		
" " 0.3		147,000	127,000	104,000	90,000	80,600	73,500	63,500		
" " 0.4		170,000	147,000	120,000	104,000	93,000	85,000	73,500		
" " 0.5		189,000	165,000	134,000	116,000	104,000	94,500	82,500		
" " 0.6		208,000	180,000	147,000	127,000	114,000	104,000	90,000		
" " 0.8 .....		.....	208,000	170,000	147,000	127,000	120,000	104,000		
" " 1.0 .....		.....	.....	189,000	165,000	132,000	134,000	116,000		
" " 1.5 .....		.....	.....	.....	201,000	147,000	165,000	142,000		
" " 2.0 .....		.....	.....	.....	.....	180,000	189,000	165,000		
" " 2.5 .....		.....	.....	.....	.....	208,000	213,000	184,000		
" " 3.0 .....		.....	.....	.....	.....	.....	.....	201,000		
DIAMETER OF PIPE 28 INCHES.										
Length in yards.....		1000	1500	2000	2500	3000	4000	5000		
Quantity delivered, with 0.5 inch pressure	1.0	198,000	161,000	140,000	125,000	114,500	99,000	88,600		
" " 1.0		280,000	229,000	198,000	167,000	161,000	140,000	125,000		
" " 1.5 .....		.....	280,000	241,000	216,000	198,000	171,000	153,500		
" " 2.0 .....		.....	.....	280,000	250,000	229,000	198,000	177,200		
" " 2.5 .....		.....	.....	.....	280,000	255,000	222,000	198,000		
" " 3.0 .....		.....	.....	.....	.....	280,000	241,000	216,000		
DIAMETER OF PIPE, 30 INCHES.										
Length in yards.....		1000	2000	3000	4000	5000	75000	10005		
Quantity delivered with 0.5 inch pressure.....	1.0	284,000	166,000	135,000	117,000	105,000	86,000	74,000		
" " 1.0		332,000	234,000	192,000	166,000	149,000	121,500	105,000		

TABLE OF THE DISCHARGE OF GAS THROUGH MAINS &c., (Continued.)

DIAMETER OF PIPE, 30 INCHES.									
Length in yards.....	1000	2000	3000	4000	5000	7500	10,000		
Quantity delivered with 1.5 inch pressure.....		287,000	284,000	203,000	182,000	149,000	128,500		
" " 2.0			270,000	234,000	210,000	172,000	149,000		
" " 2.5				263,000	234,000	192,000	166,000		
" " 3.0					257,000	210,000	182,000		
" " 4.0						243,000	210,000		
DIAMETER OF PIPE 36 INCHES.									
Length in yards.....	1000	2000	3000	4000	5000	7500	10,000		
Quantity delivered with 0.1 inch pressure.....	530,000	372,000	303,000	265,000	234,000	192,000	166,000		
" " 1.5		456,000	372,000	322,000	288,000	234,000	204,000		
" " 2.0			428,000	372,000	332,000	271,000	234,000		
" " 5.5				416,000	372,000	303,000	265,000		
" " 3.0					407,000	332,000	288,000		
" " 4.0						384,000	332,000		

The above tables are calculated upon the basis of the specific gravity of the gas being .400. The quantity of gas of any other specific gravity discharged may be ascertained by multiplying the quantity indicated in the table by .6325 (the square root of .400), and dividing by the square root of the specific gravity of the other gas.

EXAMPLE.—If a 12-inch pipe 1000 yards long discharges 23,800 cubic feet of gas per hour, specific gravity .400 at 5. in pressure, how much gas will the same pipe discharge, at the same pressure, when the specific gravity is .560 ?

$$\begin{array}{r} 23,800 \times .6325 = 20.116 \text{ cubic feet.} \text{—Answer.} \\ \hline .7483. \end{array}$$

The quantity of gas discharged at any other pressure, may be ascertained by multiplying the quantity indicated in the table by the square root of the new pressure, and dividing by the square root of the original pressure.

EXAMPLE.—If a quantity of gas equal to 23.355 cubic feet is discharged in one hour at a pressure of 1.2 inches what quantity will be discharged through the same pipe at 2.2 inches pressure ?

$$\begin{array}{r} 23.355 \times 1.4832 = 31.623 \text{ cubic feet.} \text{—Answer.} \\ \hline 1.0954. \end{array}$$

Below will be found tables giving the square roots of specific gravities from .350 to .700, rising .005 at a time, and of the square roots of pressures from $\frac{1}{16}$ of an inch to 4 inches, rising $\frac{1}{16}$ at a time.

The discharge of gas will be doubled when the length of the pipe is only one-fourth of any of the lengths given in the table.

The discharge of gas will be only one-half when the length of of the pipe is four times greater than the length given in the tables.

The discharge of gas will be doubled by the application of four times the pressure.

TABLE.

SQUARE ROOT OF THE SPECIFIC GRAVITY OF GAS FROM .350 TO .700.

Specific Gravity.	Square Root.	Specific Gravity.	Square Root.	Specific Gravity.	Square Root.	Specific Gravity.	Square Root.	Specific Gravity.	Square Root.
.350	.5916	.425	.6519	.500	.7071	.575	.7583	.650	.8062
.355	.5958	.430	.6557	.505	.7106	.580	.7616	.655	.8098
.360	.6000	.435	.6595	.510	.7141	.585	.7648	.660	.8124
.365	.6041	.440	.6633	.515	.7176	.550	.7681	.665	.8155
.370	.6083	.445	.6671	.520	.7212	.595	.7713	.670	.8185
.375	.6124	.450	.6708	.525	.7246	.500	.7746	.675	.8216
.380	.6164	.455	.6745	.530	.7280	.505	.7778	.680	.8246
.385	.6205	.460	.6782	.535	.7314	.610	.7810	.685	.8276
.390	.6245	.465	.6819	.540	.7348	.615	.7842	.690	.8306
.395	.6285	.470	.6856	.545	.7382	.620	.7874	.695	.8337
.400	.6325	.475	.6892	.550	.7416	.625	.7905	.700	.8367
.405	.6364	.480	.6928	.555	.7449	.630	.7937	.705	.8395
.410	.6403	.485	.6964	.560	.7483	.635	.7969	.710	.8426
4.15	.6442	.490	.7000	.565	.7517	.640	.8000	.715	.8455
4.20	.6481	.495	.7035	.570	.7549	.645	.8031	.720	.8485

TABLE.

SQUARE ROOT OF PRESSURE, RISING BY TENTHS OF AN INCH,
FROM ONE TENTH TO FOUR INCHES.

Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.
1-10th.	.3162	1-5-10ths.	1.2251	2-9-10ths.	.10729
2-10th.	.4572	1-6 "	1.2649	3 inches.	1.7320
3 "	.5477	1-7 "	1.3038	3-1-10th.	1.7606
4 "	.6324	1-8 "	1.3416	3-2 "	1.7888
5 "	.7071	1-9 "	1.3784	3-3 "	1.8165
6 "	.7245	2-inches.	1.4142	3-4 "	1.8439
7 "	.8366	2-1-10th.	1.4491	3-5 "	1.8708
8 "	.8944	2-2-10ths.	1.4832	3-6 "	1.8973
9 "	.9487	2-3 "	1.5165	3-7 "	1.9235
1 inch.	1.0000	2-4 "	1.5491	3-8 "	1.9493
1-1-10th.	1.0488	2-5 "	1.5811	3-9 "	1.9748
1-2-10ths.	1.0954	2-6 "	1.6123	4 inches.	2.0000
1-3 "	1.1400	2-7 "	1.6431		
1-4 "	1.1832	2-8 "	1.6733		

SIZE, WEIGHT AND STRENGTH OF MATERIALS.

SIZES OF DRAWING PAPER.

	Ft.	in.	Ft.	in.		Ft.	in.	Ft.	in.		
Antiquarian...	4.	4	×	2.	7	Double Crown.	3.	6	×	1.	8
“ extra.	4.	8	×	3.	4	Imperial.....	2.	6	×	1.	10
D'ble elephant	3.	4	×	2.	3	Super Royal...	2.	3	×	1.	7
Atlas.....	2.	10	×	2.	2	Royal	2.	0	×	1.	7
Columbia.....	2.	10	×	1.	11	Medium	1.	10	×	1.	5
Elephant	2.	3½	×	1.	10½	Demy	1.	8	×	1.	3

The sizes most in use by architects and engineers are Double Elephant, Imperial and Antiquarian ; the latter being used mostly for Patent Office drawings. The U. S. Patent Office Rules require the drawings to be made on paper or Bristol board of sufficient stiffness to stand upright in the port folios. The paper or bristol board must be 10 by 15 inches, and the drawings must be entirely within a line 8 by 13 inches, leaving one inch margin all around. Bristol board, with the border line printed on it, can now be obtained at any place where drawing paper is kept in stock.

Whatman's English drawing paper is made in two ways, viz: "Hot pressed" and "Cold pressed ;" the former leaving a fine smooth surface, and the latter a grained or rough surface, making the cold pressed more suitable for colored drawings, and the hot pressed better for fine line drawings.

In fitting up an office with drawing boards but two sizes are generally made, the large boards being 42 by 29 inches, and the smaller ones 32 by 24 inches ; these two sizes holding the Double Elephant and Imperial paper.

COPYING DRAWINGS

WITH FERRO-PRUSSATE OR BLUE PRINT PAPER.

This method of copying drawings has the advantage of cheapness combined with simplicity. Any number of copies can be made from a tracing without any other detriment to it than that arising from handling.

The tracings should be made with jet black india ink, and fine lines should be avoided. The heavier and more open the lines are drawn, the better.

The paper is prepared as follows—

Dissolve one ounce of Citrate of Iron and Ammonia in four fluid ounces of water—

Dissolve one ounce of Red Prussiate of Potash in six fluid ounces of water.

Each of the solutions should be filtered through filter paper.

As the solutions deteriorate very fast when mixed together, only as much as is wanted for immediate use should be mixed, taking equal quantities of each solution.

The mixture should be of a light-lemon yellow when applied to the paper, which is done with a soft flat brush about 3 inches wide.

A little practice is necessary to lay the mixture evenly on the paper, the brush being swept across the paper from side to side until the yellow tint is uniform all over the sheet. This should be done in a partially darkened room, and the paper afterward placed in a closed shallow drawer, such as drawings are kept in. After the sheets are dry they should be placed under drawings, or in tin tubes to exclude the light.

A printing frame with a glass cover is used for exposing the paper to the sun, the tracing being placed face up over the prepared paper. A trial will have to be made of the length of time necessary, as it depends on the intensity of the light. On a hot summer day two minutes should be sufficient, but the usual time in ordinary sun light is from ten to twenty minutes.

After sufficient exposure, which will be indicated by the changing of the yellow tint to a bronze green, the print must be washed in a bath of cold water—when the paper will turn to a bright blue, leaving the lines of the drawing white. It can then be hung on a line or pinned to a board to dry.

A new method of making "Blue Prints," especially of large size, was presented by Prof. Thurston at a recent meeting of the Society of Mechanical Engineers. This process, invented by Prof. E. C. Cleaves, of the Cornell University, is described as follows: By the common method the larger sizes are difficult to

make, the plate glass needed for the apparatus being very costly, and subject to serious risk by breakage. By the process of Prof. Cleaves no glass or frame is required, and the size and cost of the apparatus bear very little relation one to the other. The apparatus consists of a cylinder of a length exceeding that of the widest drawing to be reproduced, and of a diameter such that the longest tracing to be used can be wrapped around it, with sufficient space to spare to give room for the clamps, by which it is drawn into place and held.

The cylinder is smoothly covered with felt, and the sensitive paper carefully wrapped around it, the tracing to be copied being drawn over the whole, and held smoothly in place by spring clamps.

The apparatus being ready for use, it is mounted on a cradle, supported by its gudgeons, and is revolved in the sun by means of a cord leading from some convenient shafting, or by hand, until the exposure is completed.

It takes more time to print a sheet by this method than by the old, as the tracing is but one-half the time exposed to the rays of the sun.

THICKNESS OF THE BIRMINGHAM WIRE GAUGE.

No. of Gauge.	Thickness in decimals of an inch.	No. of Gauge.	Thickness in decimals of an inch.	No. of Gauge.	Thickness in decimals of an inch.
0000	.454	8	.165	19	.042
000	.425	9	.148	20	.035
00	.380	10	.134	21	.032
0	.340	11	.120	22	.028
1	.300	12	.109	23	.025
2	.284	13	.095	24	.022
3	.259	14	.083	25	.020
4	.238	15	.072	26	.018
5	.220	16	.065	27	.016
6	.203	17	.058	28	.014
7	.180	18	.049	29	.013
				30	.012

IRON WIRE.

TABLE, SHOWING SIZE, WEIGHT, LENGTH AND STRENGTH.

Number of Wire gauge.	Diameter in decimals of 1 inch.	Feet to the lb.	Weight of 1 foot, in lbs.	Weight of 1 mile, in lbs.	Length of 1 Bundle (63 lbs.), in yards.	Area of section in decimals of a square inch.	Actual breaking weight, in lbs.	Tensile strength per sq. in. of sec., in pounds.
00000	.450	1.863	.5366	2845.34	39.12	.15904	12598	78903
0000	.400	2.358	.4240	2238.86	49.52	.12566	9955	79326
000	.360	2.911	.3435	1813.56	61.13	.10179	8124	79813
00	.330	3.465	.2886	1523.86	72.77	.08553	6880	80437
0	.305	4.057	.2465	1301.65	85.20	.07306	5926	81110
1	.285	4.645	.2154	1136.66	97.55	.06379	5226	81925
2	.265	5.374	.1861	982.59	112.85	.05515	4570	82873
3	.245	6.286	.1591	839.91	132.01	.04714	3948	83756
4	.225	7.454	.1342	708.36	156.53	.03976	3374	84862
5	.205	8.976	.1114	588.14	188.50	.03301	2839	86000
6	.190	10.453	.09566	505.10	219.51	.02835	2476	87340
7	.175	12.322	.08115	428.49	258.75	.02405	2136	88802
8	.160	14.736	.06786	358.30	309.46	.02011	1813	90153
9	.145	17.950	.05571	294.15	376.95	.01651	1507	91276
10	.130	22.333	.04477	236.42	468.99	.01327	1233	92890
11	.1175	27.340	.03658	193.12	574.14	.01084	1010	93194
12	.105	34.219	.02922	154.30	718.60	.00866	810	93530
13	.0925	44.092	.02268	119.75	925.93	.00672	631	93917
14	.080	58.916	.01697	89.62	1237.24	.00593	474	84299
15	.070	76.983	.01299	68.59	1616.66	.00385	372	96703
16	.061	101.488	.00985	52.03	2131.25	.00292	292	90922
17	.0525	137.174	.00729	38.49	2880.65	.00216	222	102740
18	.045	186.335	.00537	28.34	3913.04	.00159	169	106343
19	.040	262.238		20.13	5506.99	.00113	124	109352
20	.0355	344.828		15.31	7241.89	.00086	96	111184

The columns giving the breaking weight and tensile strength per square inch of section, show the average results of experiments made with TRENTON IRON CO.'S WIRE.

SIZES OF WIRE.

EXPRESSED IN FRACTIONS OF AN INCH.

(APPROXIMATE.)

No. 00000, - - -	$\frac{3}{32}$	No. 3, (full,) - -	$\frac{1}{4}$	No. 14, (small,) -	$\frac{5}{16}$
" 0000, - - -	$\frac{1}{8}$	" 5, - - -	$\frac{3}{16}$	" 16, (full,) -	$\frac{1}{8}$
" 000, - - -	$\frac{3}{16}$	" 6, (small,) -	$\frac{5}{16}$	" 18, (full,) -	$\frac{3}{16}$
" 00, - - -	$\frac{1}{4}$	" 8, (small,) -	$\frac{3}{8}$	" 20, - - -	$\frac{1}{4}$
" 1, (small) -	$\frac{5}{16}$	" 10, - - -	$\frac{1}{2}$	" 28, - - -	$\frac{3}{4}$
" 2, - - -	$\frac{1}{2}$	" 13, - - -	$\frac{5}{8}$	" 36, - - -	$\frac{7}{8}$

TABLE.

GIVING THE WEIGHT OF SQUARE AND ROUND PLATES OF CAST
IRON $\frac{1}{2}$ AND 1 INCH THICK.

Length of sides of square.	Thickness of casting.		Diameter.	Thickness of casting.	
	$\frac{1}{2}$ inch.	1 inch.		$\frac{1}{2}$ inch.	1 inch.
inches.	lbs.	lbs.	inches.	lbs.	lbs.
12	18.8	37.5	12	14.7	29.5
13	22	44	13	17.5	35
14	25.5	51	14	20	40
15	29.2	58.5	15	23	46
16	33.2	66.5	16	26	52
17	37.5	75	17	29.5	59
18	42	84	18	33	66
19	47.5	95	19	37	74
20	52	104	20	41	82
21	57.5	115	21	45	90
22	63	126	22	49.5	99
23	69	138	23	54	108
24	75	150	24	59	118
25	81.5	163	25	64.5	129
26	88	176	26	69.5	139
27	95	190	27	74.5	149
28	102	204	28	80	160
29	109.5	219	29	86	172
30	117.5	235	30	92.5	185
31	125.5	251	31	98.5	197
32	133.5	267	32	105	210
33	142	284	33	111.5	223
34	150.5	301	34	118.5	237
35	159.5	319	35	125.5	251
36	169	338	36	133	266
37	178.5	357	37	140	280
38	188	376	38	148	296
39	198.5	397	39	155.5	311
40	208.5	417	40	163.5	327
41	219	438	41	172	354
42	229.5	459	42	180.5	361
43	241	482	43	189.5	379
44	252.5	505	44	198	396
45	264	528	45	202.5	415
46	276	552	46	217	434
47	289	576	47	226.5	453
48	300.5	601	48	236	472
49	313	626	49	24.55	491
50	326	652	50	256	512

TABLE.

GIVING THE WEIGHT OF SQUARE AND ROUND PLATES OF CAST
IRON $\frac{1}{2}$ AND 1 INCH THICK.

Length of sides of square. inches.	Thickness of casting.		Diameter. inches.	Thickness of casting.	
	$\frac{1}{2}$ inch.	1 inch.		$\frac{1}{2}$ inch.	1 inch.
	lbs.	lbs.		lbs.	lbs.
51	339	678	51	266.5	533
52	325.5	705	52	276.5	553
53	366	732	53	287.5	575
54	380	760	54	298.5	597
55	394.5	789	55	310	620
56	409	818	56	321	642
57	42.35	847	57	332.5	665
58	438	876	58	344.5	689
59	453.5	907	59	356.5	713
60	469.5	939	60	368.5	737

SHEET METAL.

WEIGHT PER SQUARE FOOT IN POUNDS AVOIRDUPOIS.

Thickness in inches.	Wrought Iron	Cast Iron.	Sheet Copper	Lead.	Zinc.
	480 lbs. per cubic ft.	450 lbs. per cubic ft.	459 lbs. per cubic ft.	712 lbs. per cubic ft.	436 lbs. per cubic ft.
$\frac{1}{16}$	2.50	2.34	2.86	3.71	2.27
$\frac{1}{8}$	5.00	4.69	5.72	7.42	4.54
$\frac{3}{16}$	7.50	7.03	8.58	11.12	6.81
$\frac{1}{4}$	10.00	9.37	11.44	14.83	9.08
$\frac{5}{16}$	12.50	11.72	14.30	18.54	11.35
$\frac{3}{8}$	15.00	14.06	17.16	22.25	13.62
$\frac{7}{16}$	17.50	16.41	20.02	25.96	15.89
$\frac{1}{2}$	20.00	18.75	22.88	29.66	18.16
$\frac{9}{16}$	22.50	21.09	25.74	33.37	20.43
$\frac{5}{8}$	25.00	23.44	28.60	47.10	22.70
$\frac{11}{16}$	27.50	25.78	31.46	40.79	24.97
$\frac{3}{4}$	30.00	28.12	34.32	44.50	27.24
$\frac{7}{8}$	32.50	30.47	37.18	48.20	29.51
$\frac{15}{16}$	35.00	32.81	40.04	51.91	31.78
$\frac{15}{16}$	37.50	35.16	42.90	55.62	34.05
1	40.00	37.50	45.75	59.33	36.33

WEIGHT OF A LINEAL FOOT OF ROLLED SQUARE IRON

IN POUNDS AVOIRDUPOIS—(480 lbs. per cubic foot.)

Side in inches.	Weight in pounds.	Side in inches.	Weight in pounds.	Side in inches.	Weight in pounds.	Side in inches.	Weight in pounds.
$\frac{1}{8}$	.050	$1\frac{1}{8}$	8.75	$3\frac{1}{8}$	32.35	$4\frac{5}{8}$	70.85
$\frac{1}{4}$	.206	$1\frac{1}{4}$	10.10	$3\frac{1}{4}$	34.98	$4\frac{3}{4}$	74.80
$\frac{3}{8}$	.463	$1\frac{3}{8}$	11.65	$3\frac{3}{8}$	37.73	$4\frac{7}{8}$	78.94
$\frac{1}{2}$	.825	2	13.27	$3\frac{1}{2}$	40.56	5	83.00
$\frac{5}{8}$	1.320	$2\frac{1}{8}$	14.96	$3\frac{5}{8}$	43.52	$5\frac{1}{8}$	87.20
$\frac{3}{4}$	1.852	$2\frac{1}{4}$	16.80	$3\frac{3}{4}$	46.57	$5\frac{1}{4}$	91.40
$\frac{7}{8}$	2.537	$2\frac{3}{8}$	18.69	$3\frac{7}{8}$	49.80	$5\frac{3}{8}$	95.90
1	3.306	$2\frac{1}{2}$	20.74	4	53.12	$5\frac{1}{2}$	100.43
$1\frac{1}{8}$	4.200	$2\frac{5}{8}$	22.82	$4\frac{1}{8}$	56.50	$5\frac{5}{8}$	105.06
$1\frac{1}{4}$	5.270	$2\frac{3}{4}$	25.11	$4\frac{1}{4}$	59.88	$5\frac{3}{4}$	109.76
$1\frac{3}{8}$	6.256	$2\frac{7}{8}$	27.40	$4\frac{3}{8}$	63.40	$5\frac{7}{8}$	114.51
$1\frac{1}{2}$	7.460	3	29.88	$4\frac{1}{2}$	67.23	6	119.52

STEEL.

WEIGHT OF ONE FOOT OF ROUND STEEL.

Diameter in inches.	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	
Weight per foot in pounds.	.167	.376	.669	1.04	1.5	2.05	2.67	3.38
	4.18	5.06	6.02	7.07	8.2	9.41	11.71	

PLIABLE IRON AND STEEL HOISTING ROPES, WITH
19 WIRES TO THE STRAND.

LIST OF JOHN A. ROEBLING'S SONS CO.

IRON.							STEEL.				
Trade Number.	Circumference in inches.	Diameter.	Breaking Strain in Tons of 2000 lbs.	Proper Working Load in T'ns of 2000 lbs.	Circumference of Hemp Rope of Equal Str'ngth	Min size of Drum or Sheave in ft.	Breaking Strain in Tons of 2000 lbs.	Proper Working Load in Tons of 2000 lbs.	Circumference of Hemp Rope of Equal Str'ngth	Min Size of Drum or Sheave in ft.	
1	6 $\frac{3}{4}$	2 $\frac{1}{4}$	74	15	15 $\frac{1}{4}$	8	107	22	.....	9	
2	6	2	65	13	14 $\frac{1}{4}$	7	97	20	.....	7	
3	5 $\frac{1}{4}$	1 $\frac{3}{4}$	54	11	13	6 $\frac{1}{4}$	78	18	15 $\frac{3}{4}$	7 $\frac{1}{4}$	
4	5	1 $\frac{5}{8}$	44	9	12	5	64	13	14 $\frac{1}{4}$	6	
5	4 $\frac{3}{8}$	1 $\frac{1}{4}$	35	7	10 $\frac{3}{4}$	4 $\frac{1}{2}$	52	11	13	5 $\frac{1}{4}$	
6	4	1 $\frac{1}{4}$	27	5 $\frac{1}{4}$	9 $\frac{1}{4}$	4	39	9	12 $\frac{1}{2}$	5	
7	3 $\frac{1}{4}$	1 $\frac{1}{8}$	20	4	8	3 $\frac{1}{2}$	30	6	10	4 $\frac{1}{4}$	
8	3 $\frac{1}{8}$	1	16	3	7	3	24	5	9 $\frac{1}{4}$	4	
9	2 $\frac{3}{4}$	$\frac{7}{8}$	11 $\frac{1}{2}$	2 $\frac{1}{2}$	6	2 $\frac{3}{4}$	20	4	8 $\frac{1}{4}$	3 $\frac{3}{4}$	
10	2 $\frac{1}{4}$	$\frac{3}{4}$	8.64	2	5	2 $\frac{1}{2}$	13	3	6 $\frac{3}{8}$	3 $\frac{1}{2}$	
10 $\frac{1}{4}$	2	$\frac{3}{8}$	5.13	2 $\frac{1}{4}$	4 $\frac{1}{2}$	2	7	2	5	3	
10 $\frac{1}{2}$	1 $\frac{5}{8}$	$\frac{1}{8}$	4.27	$\frac{3}{4}$	4	1 $\frac{3}{4}$	5	1 $\frac{1}{4}$	4 $\frac{1}{4}$	2 $\frac{1}{2}$	
10 $\frac{3}{4}$	1 $\frac{1}{2}$	$\frac{1}{8}$	3.48	$\frac{1}{2}$	3 $\frac{3}{4}$	1 $\frac{1}{2}$	.....	.....	.....	.....	

For safe working load allow one-fifth to one-seventh of the ultimate strength, according to speed, so as to get good wear from the rope. When substituting wire rope for hemp rope, it is good economy to allow for the former the same weight per foot which experience has approved for the latter.

WEIGHT OF A SQUARE FOOT OF SHEET METALS,

IN POUNDS, THICKNESS, BIRMINGHAM WIRE GAUGE.

Th'kness B. W. G.	Iron.	Copper.	Brass.	Th'kness B. W. G.	Iron.	Copper.	Brass.
30	.5	.58	.55	15	2.82	3.27	3.10
29	.56	.64	.61	14	3.12	3.60	4.43
28	.64	.74	.70	13	3.75	4.34	4.12
27	.72	.83	.79	12	4.38	5.08	4.81
26	.80	.92	.88	11	5.00	5.80	5.50
25	.90	1.04	.99	10	5.62	6.50	6.18
24	1.00	1.16	1.10	9	6.24	7.20	6.86
23	1.12	1.30	1.23	8	6.86	7.90	7.54
22	1.25	1.45	1.37	7	7.50	8.70	8.25
21	1.40	1.62	1.54	6	8.12	9.40	8.93
20	1.54	1.78	1.69	5	8.74	10.10	9.61
19	1.70	1.97	1.87	4	10.00	11.60	11.00
18	1.86	2.15	2.04	3	11.00	12.75	12.10
17	2.18	2.52	2.40	2	12.00	13.90	13.10
16	2.50	2.90	2.75	1	12.50	14.50	13.75

WEIGHT OF A LINEAL FOOT OF BAR IRON, IN POUNDS.

FLATS.

Breadth. in inches.	Thickness in Fractions of Inches.								
	$\frac{1}{8}$	5-16	$\frac{3}{8}$	7-16	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
1	.83	1.04	1.25	1.46	1.67	2.08	2.50	2.92	3.34
1 $\frac{1}{8}$	.93	1.17	1.40	1.64	1.88	2.34	2.81	3.28	3.75
1 $\frac{1}{4}$	1.04	1.30	1.56	1.82	2.08	2.60	3.13	3.65	4.17
1 $\frac{3}{8}$	1.14	1.43	1.72	2.00	2.29	2.87	3.44	4.01	4.59
1 $\frac{1}{2}$	1.25	1.56	1.87	2.19	2.50	3.13	3.75	4.38	5.01
1 $\frac{3}{4}$	1.35	1.69	2.03	2.37	2.71	3.39	4.07	4.74	5.43
1 $\frac{7}{8}$	1.46	1.82	2.19	2.55	2.92	3.65	4.38	5.11	5.84
1 $\frac{7}{8}$	1.56	1.95	2.34	2.74	3.13	3.91	4.69	5.47	6.26
2	1.67	2.08	2.50	2.92	3.34	4.17	5.01	5.84	6.68
2 $\frac{1}{8}$	1.77	2.21	2.66	3.10	3.55	4.43	5.32	6.21	7.10
2 $\frac{1}{4}$	1.87	2.34	2.81	3.28	3.76	4.69	5.63	6.57	7.52
2 $\frac{3}{8}$	1.98	2.47	2.97	3.47	3.90	4.95	5.95	6.94	7.93
2 $\frac{1}{2}$	2.08	2.60	3.13	3.65	4.17	5.21	6.26	7.30	8.35
2 $\frac{3}{4}$	2.19	2.74	3.28	3.83	4.38	5.47	6.57	7.67	8.77
2 $\frac{7}{8}$	2.29	2.87	3.44	4.01	4.50	5.74	6.88	8.03	9.18
2 $\frac{7}{8}$	2.40	3.00	3.60	4.20	4.80	6.00	7.20	8.40	9.60
3	2.50	3.13	3.75	4.38	5.01	6.26	7.51	8.76	10.02
3 $\frac{1}{8}$	2.71	3.39	4.07	4.74	5.43	6.78	8.14	9.49	10.86
3 $\frac{1}{4}$	2.92	3.65	4.38	5.11	5.84	7.30	8.76	10.23	11.69
3 $\frac{3}{8}$	3.13	3.91	4.69	5.47	6.26	7.82	9.39	10.95	12.52
4	3.34	4.17	5.01	5.84	6.68	8.34	10.02	11.69	13.34
4 $\frac{1}{8}$	3.54	4.43	5.32	6.21	7.09	8.87	10.64	12.42	14.19
4 $\frac{1}{4}$	3.75	4.60	5.63	6.57	7.51	9.39	11.27	13.15	15.03
4 $\frac{3}{8}$	3.96	4.95	5.91	6.94	7.93	9.91	11.89	13.88	15.86
5	4.17	5.21	6.20	7.30	8.35	10.44	12.52	14.61	16.70
5 $\frac{1}{8}$	4.38	5.47	6.57	7.67	8.76	10.96	13.14	15.34	17.53
5 $\frac{1}{4}$	4.59	5.73	6.88	8.03	9.18	11.48	13.77	16.07	18.31
5 $\frac{3}{8}$	4.80	6.00	7.20	8.40	9.00	12.00	14.40	16.80	19.20
6	5.01	6.25	7.51	8.76	10.02	12.53	15.03	17.53	20.05
6 $\frac{1}{8}$	5.43	6.77	8.14	9.49	10.86	13.56	16.28	18.98	21.72
7	5.84	7.30	8.70	10.22	11.60	14.60	17.52	20.40	23.48
7 $\frac{1}{8}$	6.25	7.82	9.38	10.94	12.52	15.64	18.78	21.90	25.04
8	6.68	8.34	10.02	11.68	13.34	16.68	20.04	23.38	26.70

WEIGHT OF A LINEAL FOOT OF ROLLED ROUND IRON IN POUNDS AVOIRDUPOIS.

(480 LBS. PER CUBIC FOOT.)

Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.
$\frac{1}{16}$	0.010	$2\frac{3}{8}$	14.77	$5\frac{5}{8}$	82.79	$8\frac{7}{8}$	206.2
$\frac{1}{8}$	0.041	$2\frac{1}{2}$	16.36	$5\frac{3}{4}$	86.52	9	212.2
$\frac{3}{16}$	0.091	$2\frac{5}{8}$	18.04	$5\frac{1}{2}$	90.34	$9\frac{1}{8}$	218.0
$\frac{1}{4}$	0.163	$2\frac{1}{2}$	19.80	6	94.26	$9\frac{1}{4}$	223.9
$\frac{5}{16}$	0.255	$2\frac{7}{8}$	21.64	$6\frac{1}{8}$	98.18	$9\frac{3}{8}$	230.1
$\frac{3}{8}$	0.368	3	23.56	$6\frac{1}{4}$	102.20	$9\frac{1}{2}$	236.2
$\frac{7}{16}$	0.501	$3\frac{1}{8}$	25.56	$6\frac{3}{8}$	106.40	$9\frac{5}{8}$	242.5
$\frac{1}{2}$	0.655	$3\frac{1}{4}$	27.64	$6\frac{5}{8}$	110.60	$9\frac{3}{4}$	248.9
$\frac{9}{16}$	0.828	$3\frac{3}{8}$	29.82	$6\frac{3}{4}$	114.90	$9\frac{7}{8}$	255.2
$\frac{5}{8}$	1.022	$3\frac{1}{2}$	32.07	$6\frac{7}{8}$	119.30	10	261.7
$\frac{11}{16}$	1.237	$3\frac{5}{8}$	34.39	7	123.70	$10\frac{1}{8}$	268.4
$\frac{3}{4}$	1.473	$3\frac{3}{4}$	36.81	$7\frac{1}{8}$	128.30	$10\frac{1}{4}$	275.0
$\frac{13}{16}$	1.728	$3\frac{7}{8}$	39.30	$7\frac{1}{4}$	132.90	$10\frac{3}{8}$	281.8
$\frac{7}{8}$	2.004	4	41.88	$7\frac{3}{8}$	137.60	$10\frac{1}{2}$	288.6
$\frac{15}{16}$	2.301	$4\frac{1}{8}$	44.57	$7\frac{1}{2}$	142.30	$10\frac{5}{8}$	295.6
1	2.618	$4\frac{1}{4}$	47.28	$7\frac{5}{8}$	147.30	$10\frac{3}{4}$	302.5
$1\frac{1}{8}$	3.310	$4\frac{3}{8}$	50.10	$7\frac{3}{4}$	152.20	$10\frac{7}{8}$	309.5
$1\frac{1}{4}$	4.094	$4\frac{1}{2}$	53.02	$7\frac{7}{8}$	157.20	11	316.8
$1\frac{3}{8}$	4.950	$4\frac{5}{8}$	56.03	8	162.40	$11\frac{1}{8}$	323.9
$1\frac{1}{2}$	5.885	$4\frac{3}{4}$	59.05	$8\frac{1}{8}$	167.50	$11\frac{1}{4}$	331.3
$1\frac{5}{8}$	6.911	$4\frac{7}{8}$	62.17	$8\frac{1}{4}$	172.80	$11\frac{3}{8}$	338.7
$1\frac{3}{4}$	8.018	5	65.49	$8\frac{3}{4}$	178.20	$11\frac{1}{2}$	346.2
$1\frac{7}{8}$	9.205	$5\frac{1}{8}$	68.71	$8\frac{5}{8}$	183.60	$11\frac{5}{8}$	353.7
2	10.470	$5\frac{1}{4}$	72.13	$8\frac{1}{2}$	189.10	$11\frac{3}{4}$	361.5
$2\frac{1}{4}$	11.820	$5\frac{3}{8}$	76.65	$8\frac{5}{8}$	194.80	$11\frac{7}{8}$	369.1
$2\frac{1}{2}$	13.250	$5\frac{1}{2}$	79.17	$8\frac{3}{4}$	200.40	12	376.9

**WEIGHT OF MATERIALS USED IN BUILDING IN LBS.
SQUARE FOOT, FROM ONE INCH TO A CUBIC
FOOT.**

STONES, EARTHS, &C.

Thickness in Inches.	Brick.			Common Gravel.	Limestone.	Marble Average.	Mortar.	Mud.	Oyster Shells.
	Average.	Fire.	Brickwork						
1	8.50	11.41	9.33	9.08	16.5	14.08	8.16	8.5	10.83
2	17.00	23.83	18.66	18.16	33.0	28.16	16.33	17.0	21.66
3	25.50	34.24	28.00	27.24	49.5	42.25	24.50	25.5	32.49
4	34.00	45.66	37.33	36.33	66.0	56.32	32.66	34.0	43.33
5	42.50	57.08	46.66	45.41	82.5	70.40	40.83	42.5	54.16
6	51.00	68.50	56.00	54.50	99.0	84.48	49.00	51.0	65.00
7	59.50	80.00	65.33	63.60	115.5	98.56	57.16	59.5	75.83
8	68.00	91.32	74.66	72.66	132.0	112.64	65.32	68.0	86.66
9	76.50	102.75	84.00	81.75	148.5	126.72	72.50	76.5	97.50
10	85.00	114.16	93.33	90.83	165.0	140.80	81.66	85.0	108.33
11	93.50	125.60	102.66	99.13	181.5	154.90	89.82	93.5	119.16
12	102.00	137.00	112.00	109.00	198.0	169.00	98.00	102.0	130.0

STONES, EARTHS, &C.

Thickness in Inches.	Portland Cement.	Concrete Average.	Earth Common Soil.	Glass window	Common sand	Slate.	Granite.		Rain water.
							Petapaco.	Susquehanna.	
1	6.75	10.41	11.41	13.75	8.66	12.25	13.75	14.08	5.21
2	13.50	20.83	22.83	27.50	17.33	24.50	27.50	28.16	10.42
3	20.25	31.25	34.25	41.25	26.00	36.75	41.25	42.24	15.62
4	27.00	41.66	45.66	55.00	34.66	49.00	55.00	56.32	20.83
5	33.75	52.08	57.08	68.75	43.33	61.25	68.72	70.40	26.04
6	40.50	64.50	68.50	82.50	52.00	73.50	82.50	84.48	31.24
7	47.25	73.00	80.00	96.25	60.66	85.75	96.25	98.56	36.45
8	54.00	83.32	91.32	110.00	69.22	98.00	110.00	112.64	41.66
9	60.75	93.75	102.75	123.75	80.00	110.25	123.75	126.72	46.87
10	67.50	104.16	114.16	137.50	86.66	122.50	137.50	140.80	52.08
11	74.25	114.57	125.57	150.25	95.32	134.75	150.25	154.88	57.28
12	81.00	125.00	137.00	165.00	104.00	147.00	165.00	169.00	62.50

WEIGHT OF 100 BOLTS WITH SQUARE HEADS AND NUTS.

Length under Head.	DIAMETER OF BOLTS.						
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 inch.	3 $\frac{1}{2}$	9	20	32 $\frac{1}{2}$	.....	.....	.....
1 $\frac{1}{2}$ "	3 $\frac{7}{8}$	9 $\frac{7}{8}$	21	34	.....	.....	.....
1 $\frac{3}{4}$ "	4 $\frac{1}{2}$	10 $\frac{3}{4}$	22	37	.....	.....	.....
1 $\frac{1}{2}$ "	4 $\frac{5}{8}$	11 $\frac{1}{8}$	23	39 $\frac{1}{2}$	.....	.....	.....
2 "	5	12 $\frac{1}{2}$	24	42	70	130	180
2 $\frac{1}{2}$ "	5 $\frac{5}{8}$	13 $\frac{1}{2}$	25 $\frac{1}{2}$	44 $\frac{1}{2}$	73 $\frac{1}{2}$	132 $\frac{1}{2}$	185
2 $\frac{3}{4}$ "	5 $\frac{3}{4}$	14 $\frac{5}{8}$	27	47	67	135	190
2 $\frac{1}{2}$ "	6 $\frac{1}{8}$	15 $\frac{1}{2}$	28 $\frac{1}{2}$	49 $\frac{1}{2}$	80 $\frac{1}{2}$	137 $\frac{1}{2}$	195
3 "	6 $\frac{1}{2}$	16 $\frac{1}{2}$	30	52	84	140	200
3 $\frac{1}{2}$ "	7 $\frac{1}{8}$	18 $\frac{3}{8}$	33	56 $\frac{1}{2}$	90	148	210
4 "	7 $\frac{3}{4}$	20	36	61	96	156	220
4 $\frac{1}{2}$ "	8 $\frac{3}{8}$	21 $\frac{5}{8}$	39	65 $\frac{1}{2}$	101 $\frac{1}{2}$	164	230
5 "	9	23 $\frac{1}{2}$	42	79	107	172	240
5 $\frac{1}{2}$ "	9 $\frac{1}{4}$	24 $\frac{3}{4}$	45	74	112 $\frac{1}{2}$	180	251
6 "	10 $\frac{5}{8}$	26 $\frac{1}{2}$	48	78	118	188	262
7 "	11 $\frac{3}{4}$	29 $\frac{1}{2}$	54	86	130	204	284
8 "	13 $\frac{1}{8}$	33	60	94	143	220	306
9 "	14 $\frac{1}{2}$	36	66	102	156	236	328
10 "	16	40	72	110	170	252	350
11 "	17 $\frac{1}{2}$	43	78	118	185	268	372
12 "	18 $\frac{3}{4}$	46	84	127	200	284	393

WEIGHTS OF NUTS AND BOLT-HEADS IN POUNDS.

FOR CALCULATING THE WEIGHT OF LONGER BOLTS.

Diameter of Bolt, in ins.	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
Weight of Hexagon Nut and Head.....	.017	.057	.128	.267	.43	.73
Weight of Square Nut and Head.....	.021	.069	.164	.320	.55	.88

Diameter of Bolt, in ins.	1	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3
Weight of Hexagon Nut and Head.....	1.10	2.14	3.78	5.6	8.75	17	28.8
Weight of Square Nut and Head.....	1.31	2.56	4.42	7.0	10.5	21	36.4

BOLTS.

For Rough Bolts.—The distance between parallel sides of bolt head and nut = $1\frac{1}{2}$ dia. of bolt $\times \frac{1}{8}$ th inch.

Thickness of head = $\frac{1}{4}$ distance between parallel sides, Thick-
ness of nut = dia. of bolt.

For Finished Bolts.—Thickness of head = thickness of nut.

Distance between parallel sides of bolt, head and nut, $\frac{1}{8}$ inch less than for rough bolts.

TENSILE STRENGTH OF MATERIALS.

WEIGHT OR POWER REQUIRED TO TEAR ASUNDER ONE
SQUARE INCH.

METALS.

	Lbs.		Lbs.
Copper, wrought....	34000	Iron plates, mean E'gl	51000
“ rolled.....	36000	“ “ lengthwise	53800
“ cast, Am ...	24250	“ “ crosswise.	48800
“ Wire.....	61200	“ inferior bar....	30000
“ bolt.....	36800	“ wire, Am.....	73600
Iron, cast Low Moor.	14076	“ “ “ 16 dia.	80000
“ Clyde No. 1...	16125	“ scrap.....	53400
“ “ No. 3...	23468	Lead, cast.....	1800
“ Stirling, mean.	25764	“ Milled.....	3320
“ American, “	31829	“ wire.....	2580
“ English, “	19484	Platinum wire.....	53000
“ Greenwood Am	45970	Silver cast... ..	40000
“ gun-metal, mean	37232	Steel cast maximum.	142000
“ wrought wire..	103000	“ “ mean.....	88657
“ best Swedish bar	72000	“ blistered, soft..	133000
“ “ Russian “	59500	“ “ “ “	104000
“ “ English “	56000	“ shear.....	124000
“ rivets, Am.....	53300	“ blister.....	133000
“ bolts.....	52250	“ puddled extreme	173817
“ hammered....	53913	“ “ or semi iron	121408
“ mean of English	53900	“ plates lengthwise	96300
“ rivets “	65000	“ “ crosswise..	93700
“ crank shaft....	44750	“ razor.....	150000
“ plates, boiler Am	48000	Tin, cast block.....	5000
“ “ “ “	62000	“ Banca.....	2122
“ Lake Superior.	90000	Zinc.....	3500

MISCELLANEOUS SUBSTANCES.

	Lbs.		Lbs.
Brick well burned...	750	Limestone.....	{ 670
“ fire.....	65	“ “ “ “	{ 2800
“ inferior.....	{ 290	Marble, Italian.....	5200
	{ 100	“ White.....	9000
Cement, blue stone..	77	Mortar 12 years old..	60
“ hydraulic...	234	Plaster of Paris.....	72
“ Harwich ...	30	Rope Manilla.....	9000
“ Portland 6 mos.	414	“ hemp tarred...	15000

TENSILE STRENGTH OF MATERIALS.

WEIGHT OR POWER REQUIRED TO TEAR ASUNDER ONE
SQUARE INCH.

MISCELLANEOUS SUBSTANCES.

	Lbs.		Lbs.
Cement, Sheppy.....	24	Rope wire	3700
" P'tl'd 1, Sand 3	280	Sandstone, fine grain	200
Chalk	118	Slate	12000
Glass, crown.....	2346	Stone-bath.....	352
Gutta percha.....	3500	Spruce	10100
Hydraulic lime.....	40	Lignumvitae.....	11800
" " mortar	140	Maple.....	10600
Ivory.....	16000	Pine, White.	8000
Leather, belts.....	330	Whalebone.....	7600

COMPOSITIONS.

	Lbs.		Lbs.
Gold 5, Copper 1....	50000	Copper 10, Tin 1....	32000
Brass.....	42000	" 8, " 1 (bar)	30000
" yellow.....	18000	" 8, " 1 small	50000
Bronze, least.....	16698	Tin 10, Antimony 1.	11000
" greatest.....	56788	Yellow metal.....	48700

HASWELL.

TENSILE STRENGTH.

Tensile strength is the resistance of the fibres or particles of a body to separation.

WROUGHT IRON, TIE RODS, COMMON ENGLISH IRON
 $1\frac{3}{16}$ INCHES DIAMETER.

DESCRIPTION OF CONNECTION.	BREAKING WEIGHT.
Semicircular hook fitted to a circular and welded eye	14000 lbs.
Two semicircular hooks hooked together.....	16220 "
Right angled hook, fitted into a cylindrical eye....	29120 "
Two links or welded eyes connected together.....	48160 "
Straight rod without any connected articulation....	56000 "

TRANSVERSE STRENGTH OF MATERIALS, EXPERIMENTS OF VARIOUS AUTHORS.

REDUCED TO THE UNIFORM MEASURE OF ONE INCH SQUARE AND ONE FOOT IN
LENGTH; WEIGHT SUSPENDED FROM ONE END.

Materials.	Breaking Weight.	Value for General Use.	Materials.	Breaking Weight.	Value for General Use.
Metals.	Lbs.		Wrought Iron.	Lbs.	
Am. Cast Iron	507	125 to 250		700	
(Four Grades.)	733		American	650	160 to 200
West Pt. Foundry..	681	170 to 225		600	
English	472	110 to 140	English.....	400	100 to 130
Steel (greatest)....	1918	350 to 450	"	550	135 to 180
" puddled	800	170 to 225	Swedish	665	165 to 210
Woods.					
Ash.....	163	55	Copper... ..		55
Beech.....	130	32	Brass		58
Birch	160	40	Stones (American)...		
Chestnut.....	160	53	Flagging, blue.....	31	10
White Pine.....	92	30	Freestone, Conn.....	13	4
Elm.....	125	30	" Dorchester..	10.8	3½
Hickory.....	250	55	" New Jersey.	20.1	6½
Locust	295	80	" " York..	17.8	6
Maple.....	202	65	" " " York..	24	8
Norway Pine.....	123	40	Granite, blue.....	18	6
Oak, African.....	208	50	" Quincey Mass.	26	8½
" Am. White...	230	50	Stones (English)....		
" " Live.....	245	55	Adelaide, marble....	4.5	1½
" Canadian	146	36	Bangor Slate.....	90	30
" English	140	35	Cornish granite..	22	7
Pine, Yellow.....	136	45	Limestone	11	3½
Whitewood	116	38	Portland, oolite.....	21.2	7
			Yorkshire, blue.....	26	8½

INCREASE IN STRENGTH OF SEVERAL WOODS BY SEASONING.

Ash..... 44.7 per cent	Elm..... 12.3 per cent	White Pine 9 per cent
Beech 61.9 " "	Oak 26.1 " "	

CHAINS, HEMP AND WIRE ROPES.

Safety Proof.	INCHES AND 16ths.			WEIGHT PER FATHOM.			Ultimate Strain.
	Chain.	Hemp.	Wire.	Chain.	Hemp.	wire.	
	Diam.	Cir.	Cir.	Lbs.	Lbs.	Lbs.	
Cwt.							Cwt.
1.3	$\frac{1}{8}$	0.10	0.4	0.23	0.08	0.06	2.6
4.5	$\frac{1}{4}$	1.6	0.8	0.93	0.47	0.24	9
10	$\frac{3}{8}$	2.1	0.12	2.11	1.06	0.54	20
18	$\frac{1}{2}$	2.12	1.1	3.75	1.89	1.10	35
28	$\frac{5}{8}$	3.7	1.6	5.86	2.94	1.83	55
40	$\frac{3}{4}$	4.2	1.10	8.45	4.52	2.56	80
55	$\frac{7}{8}$	4.15	1.14	11.5	6.09	3.42	109
69	1	5.8	2.2	15.0	7.55	4.39	138
80	$1\frac{1}{8}$	6.3	2.6	18.8	9.56	5.48	160
94	$1\frac{1}{4}$	6.14	2.11	23.0	11.8	7.00	218
109	$1\frac{1}{2}$	7.9	2.15	27.7	14.3	8.38	187
127	$1\frac{3}{4}$	8.4	3.3	33.0	17.1	9.90	254
147	2	8.15	3.8	38.5	19.9	11.9	293
168	$2\frac{1}{4}$	9.10	3.12	44.7	23.1	13.6	335
199	$2\frac{1}{2}$	10.5	4.1	51.1	26.3	16.0	397
220	1 inch.	11.	4.6	58.0	30.2	18.6	440
246	$1\frac{1}{8}$	11.11	4.11	65.6	34.1	21.3	492
278	$1\frac{1}{4}$	12.6	5 inch.	73.7	38.2	24.2	545
302	$1\frac{1}{2}$	13.1	5.5	82.1	42.6	27.4	604
332	$1\frac{3}{4}$	13.12	5.10	91.0	47.1	30.7	663
365	2	14.7	6 inch.	100	52.0	35.0	730
399	$2\frac{1}{8}$	15.2	6.5	110	57.1	38.7	798
435	$2\frac{1}{4}$	15.15	6.10	120	63.4	42.6	869
472	$2\frac{1}{2}$	16.8	6.15	131	67.9	46.7	944
553	$2\frac{3}{4}$	17.14	7.10	154	79.8	56.4	1105
638	3	19.4	8.4	178	92.6	66.0	1275
729	$3\frac{1}{8}$	20.10	8.14	205	106	76.5	1457
825	$3\frac{1}{4}$	22.00	9.8	232	121	88.0	1650
1072	$3\frac{1}{2}$	24.12	10.12	293	153	112	2141
1286	$3\frac{3}{4}$	27.8	12 inch	363	189	140	2575
1559	4	30.4	13.4	438	229	172	3117
1854	5	33.0	14.8	522	272	205	3708

RODS, NUTS, &c.

Dia. of Rod, ins.	Strength. Lbs.	Weight per foot. Lbs.	Square Nuts.		Screw Threads per inch.
			Side ins.	Depth ins.	
1½	2.280	0.66	1½	¾	12
¾	5.040	1.49	1½	¾	10
1	9.000	2.65	2	1	8
1¼	14.040	4.17	2½	1¼	7
1½	20.280	5.97	2½	1½	6
1¾	27.480	8.13	3	1¾	5
2	36.000	10.62	3½	1¾	4.5

Column 1 gives the diameter of Rod in inches; Column 2 gives the strain to which it may safely be subjected, being at the rate of 12,000 lbs. per square inch; Column 3 the weight per lineal foot; Columns 4 and 5 the side and depth of a square nut equal in strength to the rod, and column 6 the number of screw threads per inch in length.

RESISTANCE TO COMPRESSION.

Kind of Material.	Pounds.	Tons.
Oak of good quality.....	432	0.1885
Oak, Common.....	280	0.125
Spruce, red.....	540	0.241
“ white.....	140	0.0256
Iron, wrought.....	14400	6.13
“ cast.....	28750	12.85
Basalt.....	2875	1.285
Granite, hard.....	1000	0.446
“ common.....	575	0.256
Marble, hard.....	1435	0.640
“ common.....	431	0.192
Sandstone, hard.....	1295	0.577
“ common.....	5.6	0.0025
Brick, good quality.....	175.0	0.078
“ common.....	58.0	0.0259
Limestone, hardest kind.....	720.0	0.321
“ common.....	432.0	0.193
Plaster of Paris.....	86.0	0.0384
Mortar, good quality, 18 months old.....	58.0	0.0259
“ common.....	36.0	0.016

When the height or length of the column is more than 12 times its smallest thickness, divide the tabular weight by the corresponding number in the following table.

Length $\times$ thickness	12	18	24	30	36	42	48	54	60
Divide by.....	1.2	1.6	2	2.8	4	5	6	8	12

The table shows the weight a column can bear with *safety*, when the weight presses through the length of the column. The tabular number is the weight in pounds or tons per square inch on the transverse section of a column of a length less than 12 times its smallest thickness.

EXAMPLE.—A building which is to weigh 2000 tons is to be supported by piles of red spruce 18 feet in length and 12 inches diameter. How many piles are required to support the building?

$$\frac{12^2 \times 0.785 \times 0.241}{1.6} = 17 \text{ tons,} \quad \text{the weight which each pile can bear—}$$

Ans. and $\frac{2000}{17} = 118 \text{ piles.}$

NYSTROM.

COHESIVE STRENGTH PER SQUARE INCH OF CROSS SECTION

Kind of Materials.	Just tear asunder		With Safety.	
	Pounds.	Tons.	Pounds.	Tons.
Cast Steel.....	134256	59.93	33600	14.98
Blistered Steel.....	133152	59.43	33300	14.86
Steel shear.....	128632	56.97	32160	14.24
Iron Swedish bar.....	65000	29.2	16260	7.3
" Russian.....	59470	26.7	14900	6.7
" English.....	56000	25.0	14000	6.25
" Common over 2 in. sq...	36000	16.0	9000	4.0
" Sheet parallel rolling...	40000	17.85	10000	4.46
" At right angles to roll...	34400	15.35	8600	3.84
Cast Iron, good quality.....	45000	20.05	11250	5.00
" inferior ".....	18000	8.03	4500	2.0
Copper cast.....	32500	14.37	8130	3.6
" rolled.....	61200	27.2	15300	6.8
Tin cast.....	5000	2.23	12500	0.56
Lead cast.....	880	0.356	220	0.09
Lead rolled.....	3320	1.48	830	0.37
Platinum wire.....	53000	23.6	13250	5.9
Brass common.....	45000	20.05	11250	5.0
Wood.				
Ash.....	16000	7.14	4000	1.87
Beech.....	11500	5.13	2875	1.28
Box.....	20000	8.93	5000	2.23
Cedar.....	11400	5.09	2850	1.27
Mahogany.....	21000	9.38	5250	2.34
" Spanish.....	12000	5.36	3000	1.34
Oak, American White.....	11500	5.13	2875	1.28
" English.....	10000	4.46	2500	1.11
" seasoned.....	13600	6.07	3400	1.52
Pine, pitch.....	12000	5.35	3000	1.34
" Norway.....	13000	5.8	3250	1.45
Walnut.....	7800	3.48	1950	0.87
Whalebone.....	7600	3.40	1900	0.85
Hemp ropes, good.....	6400	2.86	2130	0.95
Manilla ropes.....	3200	1.43	1100	0.49
Wire ropes.....	38000	17.0	12000	5.36
Iron chain.....	65000	29.0	21600	9.38
" with cross pieces.....	90000	40.0	30000	13.4

TO FIND THE COHESIVE STRENGTH.

RULE.—Multiply the cross section of the material in inches by the tabular number, and the product is the cohesive strength.

EXAMPLE.—An iron bar has a cross section of 2.27 square inches. How many tons are required to tear it asunder, and how many pounds can it bear with safety?

Answer.—English iron $2.27 \times 25 = 56.75$ tons, which will tear it asunder, and it will bear with safety $2.27 \times 14000 = 31780$ lbs.

NYETROM.

SPECIFIC GRAVITY AND WEIGHT OF VARIOUS SUBSTANCES.—WATER = 1,000.

NAME OF SUBSTANCES.	Specific Gravity and Weight per Cubic Foot in Ounces.	Weight per Cubic Foot in Pounds Avoirdupois.	NAME OF SUBSTANCES.	Specific Gravity and Weight in Cubic Foot in Ounces.	Weight per Cubic Foot in Pounds Avoirdupois.
Alcohol, pure...	.790	49.38	Iron, wrought...	7.680	480
Ash (timber)....	.752	47	Lead	11.392	712
Asphalt, prepared	2.496	156	Lead, white.....	3.168	198
Basalt	2.992	187	Limestone, lias..	2.496	156
Bath Stone.....	1.792	112	" magnesian	2.848	178
Beech.....	.688	43	Lime, quick.....	.864	54
Birch.....	.704	44	Mahogany, Hon-		
Bitumen.....	.992	62	duras	.640	40
Boxwood	.960	60	Mahogany, Span-		
Brass, cast.....	8.240	515	ish.....	.720	45
Brass, wire.....	8.480	530	Maple.....	.784	49
Brick.....	2.080	130	Marble.....	2.720	170
Brickwork.....	1.792	112	Marl.....	1.728	108
Cement, Portland	1.424	89	Masonry.....	2.240	140
Cement, Roman..	.960	60	Mercury.....	13.584	849
Chalk.....	2.368	148	Mortar.....	1.760	110
Charcoal, oak...	.336	21	Mud.....	1.600	100
Clay.....	1.920	120	Naphtha.....	.848	53
Clay, puddle....	2.560	160	Oak, English....	.800	50
Coal, Anthracite.	1.280	80	Oak, American..	.864	54
" Bituminous.	1.200	75	Oil, linseed.....	.944	59
" Can'l Scotch	1.248	78	" olive.....	.912	57
" " Wigan..	1.280	80	" whale.....	.928	58
" " Newc'stle	1.312	82	" sperm.....	.880	55
Coke from cok-			" tallow.....	.896	56
ing ovens.....	.800	50	" colza	.912	57
Coke from retorts			Paving... ..	2.560	160
slacked.....	.560	35	Peat.....	1.280	80
Coke from retorts			Pebble stone....	2.704	169
unslacked.....	.448	28	Petroleum.....	.880	55
Concrete.....	1.920	120	Pitch.....	1.152	72
Copper, cast....	8.640	540	Platinum, pure..	19.520	1,220
Copper, sheet and			" hammerd	20.480	1,280
wire.....	8.800	550	" wire.....	20.800	1,300
Cork.....	.240	15	Portland stone...	2.096	131
Earth, loam....	1.600	100	Quartz.....	2.640	165
Ebony.....	1.200	75	Sand, damp.....	1.888	118
Elm.....	.560	35	" dry.....	1.440	90
Pine and spruce..	.560	35	Sandstone.....	2.528	158
Pine, American..	.464	29	Shale.....	2.592	162

**SPECIFIC GRAVITY AND WEIGHT OF VARIOUS
SUBSTANCES.—WATER = 1,000.**

NAME OF SUBSTANCES.	Specific Gravity and Weight per Cubic Foot in Ounces.	Weight per Cubic Foot in Pounds Avoirdupois.	NAME OF SUBSTANCES	Specific Gravity and Weight per Cubic Foot in Ounces.	Weight per Cubic Foot in Pounds Avoirdupois.
Larch	.544	34	Silver, pure.	10.480	655
Flag, Yorkshire..	2.288	143	“ standard..	10.528	658
Flint.....	2.624	164	Slate.....	2.880	180
Freestone.....	2.240	140	Snow.....	.128	8
Glass, crown....	2.496	156	Steel.....	7.840	490
“ plate	2.880	180	Sulphur.....	2.000	125
“ flint.....	2.992	187	Sycamore.....	.592	37
Gold, pure.....	19.360	1210	Tar.....	1.040	65
“ standard..	17.728	1108	Tile.....	1.792	112
Granite.....	2.688	168	Tin.....	7.360	460
Gravel.....	1.840	115	Water, pure....	1.000	62.5
Grindstone.....	2.096	131	“ sea.....	1.024	64.05
Gun-metal.....	8.784	549	Willow.....	.448	28
Gypsum.....	2.304	142	Yew	.800	50
Ice at 32° Fahr..	.93	57.96	Zinc.....	7.040	440
Iron, cast.....	7.168	448	.....	.....	.....

TO FIND THE SPECIFIC GRAVITY OF COAL.

Suspend a small piece of the coal, by means of a horse hair, from the underside of a carefully adjusted balance and weight it, both in and out of distilled water. Divide its weight in the air by the loss of weight in water, and the quotient is the specific gravity.

EXAMPLE.—A piece of coal weighs.....480 grains.

Loss of weight when weighed in water, 398 “

480

Then $\frac{480}{398} = 1.206$ specific gravity of the coal compared with

water = 1,000.

Specific gravity is the relative weight of equal bulks of different substance, distilled water at 62° Fahr. being taken as the standard of comparison. At this temperature a cubic foot of water

weighs 1,000 ounces avoirdupois. Hence the specific gravity of a body is also its weight in ounces avoirdupois per cubic foot ; so that knowing the specific gravity, the weight of any quantity of matter may be calculated by simple measurement. For example :—In the instance given above, the specific gravity is shown to be 1.206, the weight of the coal per cubic foot is therefore 1206 ounces, or 75.4 lbs. avoirdupois.

TO FIND THE WEIGHT OF A BODY.

RULE 1.—Multiply the contents of the body in cubic feet by 62.5, and the product by its specific gravity, will be the weight of the body in lbs. avoirdupois.

RULE 2.—Multiply the contents of the body in cubic inches by 0.03616, and the product by its specific gravity will be the weight of the body in lbs. avoirdupois.

RULE 3.—Divide the specific gravity by 0.016, and the quotient is the weight of a cubic foot.

EXAMPLE 1.—A log of beech wood is 9 in. square by 6 ft. long. What is its weight in pounds ?

$$.75 \times 6 = 4.50 \times 62.5 \times .688 = 193.5 \text{ lbs.}$$

EXAMPLE 2.—A bottle full of mercury is 3 inches inside diameter and 6 inches high, required the weight of the mercury in pounds—

$$7.068 \times 6 = 42.408 \times 0.03616 \times 13.584 = 28.83.$$

To find the specific gravity—

W = weight of body in the air.

w = " " " (heavier than water) immersed in water.

S = specific gravity of the body. Then

$$W - w . W = S \quad S = \frac{W}{W - w} \quad \text{Formula 1.}$$

EXAMPLE 3.—Required the specific gravity of a piece of iron ore weighing 6.345 lbs. in the air and 4.935 lbs. in water—

$$S = \frac{6.345}{6.345 - 4.935} = 4.5 \text{ the specific gravity.}$$

When the body is lighter than water annex to it a heavier body that is able to sink the lighter one.

S = specific gravity of the heavier annexed body.

s = " " " " lighter body.

W = weight of the two bodies in air.

w = " " " " " " water.

V = " " " heavier body in air.

v = " " " lighter " "

$$s = \frac{v}{\frac{W-w-V}{S}} \quad \text{Formula 2.}$$

EXAMPLE 4.—To a piece of wood which weighs $v = 14$ pounds in the air is annexed a piece of cast iron $V = 28$ pounds, the two bodies together weigh $w = 11.7$ pounds in water, required the specific gravity of the wood.

$$W = V + v = 28 + 14 = 42 \text{ pounds.}$$

$$S = 7.2 \text{ specific gravity of the cast iron}$$

$$\text{Formula 2. } S = \frac{14}{\frac{42-11.7-28}{7.2}} = 0.529 \left\{ \begin{array}{l} \text{the specific grav-} \\ \text{ity of the wood.} \end{array} \right.$$

The specific gravity of wood in the form of a rod may be obtained by immersing the rod vertically in the water, when the immersed end is to the whole rod, as the specific gravity is to 1.

EXAMPLE 5.—A cylinder of wood is 6 feet 3 ins. long, when immersed vertically in water it will sink 3 feet 9 ins. by its own weight, required its specific gravity.

$$3.75 : 6.25 = S : 1 \quad S = \frac{3.75}{6.25} = 0.600.$$

To discover the adulteration in metals, or to find the proportions of two ingredients in a compound.

$$V = \frac{W-s(W-w)}{1-\frac{s}{S}} \quad \text{Formula 3.}$$

EXAMPLE 6.—A metal compounded of silver and gold weighs $W = 6$ pounds in the air, and in water $w = 5.636$ pounds. Required the proportions of silver and gold?

$S = 19.36$ specific gravity of gold.

$s = 10.31$ " " " silver.

$$\text{Weight } V = \frac{6 - 10.51 (6 - 5.636)}{10.51} = 4.755 \text{ pounds of gold.}$$

Formula 3. $1 - \frac{10.51}{19.36}$ and 1.245 pounds of silver.

WEIGHT OF WROUGHT AND CAST IRON.

One cubic foot of Wrought Iron		—	480 lbs.
One square foot, one inch thick	— $\frac{480}{12}$	—	40 "
One square inch, one foot long	— $\frac{40}{12}$	—	$3\frac{1}{3}$ "
One square inch, one yard long	— $3\frac{1}{3} \times 3$	—	10 "

To find the weight of any piece of Wrought Iron. Ten times the sectional area in square inches is equal to the weight in pounds per yard.

AMERICAN SLATING.

Slating is estimated by the "square," which is the quantity required to cover 100 square feet. The slates are usually laid so that the third laps the first three inches. Therefore, to compute the number of slates of a given size required per square: Subtract three inches from the length of the slate, multiply the remainder by the width, and divide by two. This will give the number of square inches covered per slate; divide 14,400 (the number of square inches in a square) by the number so found, and the result will be the number of slates required.

The following table gives the number of slates per square for the usual sizes:

NUMBER OF SLATES PER SQUARE.

Size in Inches.	Pieces per Square.	Size in Inches.	Pieces per Square.	Size in Inches.	Pieces per Square.
6×12	533	8×16	277	12×20	141
7×12	457	9×16	246	14×20	121
8×12	400	10×16	221	11×22	137
9×12	355	9×18	213	12×22	126
7×14	374	10×18	192	14×22	108
8×14	327	12×18	160	12×24	114
9×14	291	10×20	169	14×24	98
10×14	261	11×20	154	16×24	86

The weight of slate per cubic foot is about 174 lbs., or per square foot of various thicknesses, as follows :

Thickness in inches.....	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$
Weight in Pounds.....	1.81	2.71	3.62	5.43	7.25

The weight of slating laid per sq. foot of surface covered, will, of course, depend on the size used. The weight of 10×18 slate, $\frac{3}{16}$ thick, for example, per square foot of roof, would be 5.86 lbs.

Slating laid on iron roofs, or exposed roofs, without boarding beneath it, should be laid with Asphalt Slating Cement. Slating laid in this cement, which is a composition of ground slate and asphaltum, will soon become one solid mass. This manner of slating will be found of great value for retort house roofs, particularly on the ventilators, which are generally a great source of trouble. A small quantity of the cement is laid on the joint, and the covering slate pressed down upon it. The roof is pointed up on the inside with the cement, making it virtually equal to one piece of slate for the whole roof. It can be obtained from dealers in slater's supplies. Slating on buildings where coal gas is made should be secured with extra heavy lead nails—as the sulphur and carbonic acid fumes soon destroy any other kind.

GALVANIZED ROOFING IRON.

No. Wire Gauge before Galvan- izing.	Weights per Square Foot Galvanized.		
	Flat Sheets.	Corrugated Sheets	Corrugated Sheets laid, incl. laps.
27	.978	1.09	1.30
26	1.06	1.18	1.41
25	1.14	1.27	1.52
24	1.22	1.36	1.62
23	1.34	1.49	1.79
22	1.46	1.62	1.95
21	1.63	1.81	2.17
20	1.75	1.94	2.33
19	2.03	2.26	2.71
18	2.32	2.58	3.19

Nos. 20 to 22 are usual thicknesses for roofing.

ODDS AND ENDS.

DIFFERENT TEMPERATURES AND THEIR EFFECTS.

	FAHR.		FAHR.
Greatest cold ever pro- duced.....	— 135°	Heat of human blood..	+ 98
Solid compound of alco- hol and carbonic acid melts.....	— 122	Phosphorus melts	+ 108
Greatest cold by ordinary freezing mixtures.....	— 91	Alcohol boils.....	+ 174
Temperature of the plan- etary spaces	— 53	Rose's metal melts	+ 201
Greatest cold in arctic regions.....	— 60	Newton's " "	+ 211
Sulphuric ether congeals —	47	Water boils.....	+ 212
Nitric acid congeals.....	— 45	Sulphur melts.....	+ 218
Mercury congeals	— 39	Mercury boils	+ 662
Oil of vitril freezes	+ 1	Antimony melts	+ 810
Oil of turpentine freeze-s	+ 14	Red heat.....	+ 980
Wine freezes.....	+ 20	Heat of common fire... +	1141
Blood "	+ 25	Brass melts.....	+ 1869
Ice melts.....	+ 32	Silver "	+ 1873
Olive oil freezes	+ 36	Copper "	+ 1996
		Gold "	+ 2240
		Cast iron melts.....	+ 2786

—KAHN'S ELEMENTS OF CHEMISTRY.

PIPES FOR STEAM OR HOT WATER.

Cast iron pipes used for steam or hot water should have rust joints, as lead joints from the alternate heating and cooling soon become loose.

TABLE.

INDICATING THE COMPARATIVE SALUBRITY OF THE SEVERAL
ILLUMINATING MATERIALS.

The flame of coal gas, and the flames of several combustible bodies that gave an amount of light equal to it, were burned separately in given quantities of atmospheric air, and the times were noted at which the flames were extinguished by the contamination of the air. The following were the results:

Colza oil.....	was extinguished in	71 minutes.
Olive oil	" "	72 "
Russian tallow.....	" "	75 "
Sperm oil	" "	76 "
Stearic acid.....	" "	77 "
Wax candles.....	" "	79 "
Spermaceti candles...	" "	83 "
Coal Gas (13 candles).	" "	98 "
Cannel Gas (28 candles)	" "	152 "

From which it appears that the atmosphere of a confined room lighted by cannel gas will support life twice as long as the atmosphere of the same room lighted equally by tallow candles.

NEWBIGGING.

TABLE.
OF THE VELOCITY AND FORCE OF THE WIND.

Miles per hour.	Feet per second.	Pressure in lbs. per square ft.	Description.
1	1.47	.005	Hardly perceptible.
2	2.93	.020	Just perceptible.
3	4.40	.044	
4	5.87	.079	Gentle breeze.
5	7.33	.123	
10	14.67	.492	Pleasant breeze.
15	22.00	1.107	
20	29.34	1.968	Brisk gale.
25	36.67	3.076	
30	44.01	4.429	High wind.
35	51.34	6.027	
40	58.68	7.873	Very high wind.
45	66.01	9.966	
50	73.35	12.300	Storm or Tempest.
60	88.02	17.718	
70	102.71	24.153	Great storm
80	117.36	31.490	
100	146.70	49.300	Hurricane.

The pressure or force of the wind is as the square of its velocity.

The square of the velocity of the wind in feet per second
 $\times .002288$ = pressure in lbs. per square foot.

The resistance of a sphere is about one fourth of that of its greatest circle.

NEWBIGGING.

Let P = pressure of wind in lbs. per sq. ft. against a surface perpendicular to its direction. V = velocity in miles per hour—

$$P = \frac{V^2}{200}$$

**RELATIVE VALUE OF DIFFERENT ILLUMINATING
AGENTS IN REGARD TO THEIR ILLUMINATING
PROPERTIES.—(DR. LETHBY.)**

Name.	Rate of Con- sumption per hour.	Ill. Power, (Sperm 120 grs.)	Quantity— 14 Candles.
Cannel Gas.....	4 feet.	18.67	3 feet.
Coal Gas.....	5 "	14.00	5 "
Benzole.....	301 grs	4.91	857 grs.
Paraffine Oil.....	265 "	7.11	522 "
Sperm Oil.....	686 "	10.00	960 "
Colza Oil.....	648 "	9.01	1008 "
Paraffine Candles.....	122 "	1.46	1171 "
Sperm ".....	132 "	1.35	1440 "
Wax ".....	168 "	1.43	1652 "
Stearic ".....	140 "	1.13	1732 "
Composite ".....	144 "	1.08	1858 "
Tallow ".....	145 "	0.83	2542 "

**THE HEATING AND VITIATING EFFECTS OF ILLUM.
INATING AGENTS ON THE ATMOSPHERE WHEN
BURNING SO AS TO GIVE THE LIGHT OF 12
STANDARD SPERM CANDLES.**

(DR. LETHBY.)

Name.	Lbs. of water heated 1° Fahr.	Oxygen con- sumed (Cubic Feet.)	Carbonic Acid produced (Cubic Feet.)	Air Vitiated (Cubic Feet.)
Cannel gas.....	1950	3.30	2.01	50.2
Common gas.....	2786	5.45	3.21	80.2
Sperm Oil.....	2335	4.75	3.33	83.3
Benzole.....	2326	4.46	3.54	88.5
Paraffine.....	3619	6.81	4.50	112.5
Sperm candles.....	3517	7.57	5.27	131.7
Wax ".....	3831	8.41	5.90	149.5
Stearic ".....	3747	8.82	6.25	156.2
Tallow ".....	5054	12.06	8.73	218.3

THE MELTING POINT OF METALS, &c.

	Fahr.°		Fahr.°
Wrought Iron, English hammered	2910	Antimony	810
Wrought Iron, French soft	2730	Zinc	793
Steel maximum	2550	Lead	630
“ minimum	2370	Bismuth	518
Cast Iron, grey	2190	Tin	455
“ “ very fusible	2010	Sulphur	239
“ “ white, maximum	2010	Wax, white	154
“ “ “ minimum	1920	Spermaceti	120
Gold, very pure	2280	Stearine 190° to	120
“ standard coin	2156	Phosphorus	109
Copper	2050	Tallow	92
Silver, pure	1830	Oil of Turpentine	14
Brass	1650	Common Salt, 1 Water 3 freezes	4
Mercury	—40	Sulphuric acid sp. gr. 1.6415 freezes	—45
“ (by air Thermome- ter) freezes	—37.9	Sulphuric ether freezes	—46

Temperatures above red heat, measured by an Air Thermometer.

The above figures are from experiments by Pouillet and others.

BOX ON HEAT, PAGE 11.

BOILING POINT OF LIQUIDS AT ATMOSPHERIC PRESSURE.

		Temp. Fahr. Deg.	
Ether Sulphuric sp. gr. .7365		100	Lussac.
Alcohol “ .813		173	Ure.
Muriatic Acid “ 1.047		232	Dalton.
Nitric “ “ 1.16		220	“
Sulphuric “ “ 1.3		240	“
“ “ “ 1.85		620	“
Oil of Turpentine “		316	Ure.
Naphtha		306	“
Sulphur		570	“
Linseed Oil		600	
Mercury		662	Reginault.
Water		212	

BOX ON HEAT, PAGE 14.

FACTS AND FIGURES ABOUT WATER AT ORDINARY TEMPERATURES.

1 Cb Ft. of Water weighs	1000 ounces or	62.5 lbs.	
1 " In. " " "		.03617 lbs.	
1 " Ft. " " "		7.481 Galls. Am.	
1 " " " " "		6.232 " Eng.	
1 Pint of Water =	34.65 cubic ins.	or	1.25 lbs.
1 Quart " =	69.30	" "	2.50 "
1 Gallon " =	231	" "	8.355 "
1 " " =	.13369	" "	
12½ " weigh	100 lbs.		

Water is composed of 88.9 parts by weight of Oxygen, and 11.1 parts by weight of Hydrogen, and by measure 1 part Oxygen to 2 parts Hydrogen—expressed $H_2 O$.

A cubic foot of water at $212^{\circ} F$. weighs 59.675 lbs., below $39^{\circ} F$. its density decreases, the weight of a cubic inch of ice being 57.25 lbs.

A cubic foot of Sea water weighs 64,312 lbs.

One Gallon of " " contains from 4 to 5 lbs. of salt.

WATER TESTS.

Test for hard or soft water.—Dissolve a small quantity of good soap in alcohol. Let a few drops fall into a glass of water. If it turns milky it is hard, if not, it is soft.

Test for Earthy matters or Alkali.—Take litmus paper dipped in vinegar, and if, on immersion, the paper returns to its true shade, the water does not contain earthy matter or alkali. If a few drops of syrup be added to a water containing an earthy matter it will turn green.

Test for Carbonic Acid.—Take equal parts of water and clear lime water. If combined or free carbonic acid is present, a precipitate is seen, to which, if a few drops of muriatic acid be added, an efferevescence commences.

Test for Magnesia.—Boil the water to a twentieth part of its weight, and then drop a few grains of neutral carbonate of ammonia into a glass of it, and a few drops of phosphate of soda. If magnesia be present it will fall to the bottom.

Test for Iron.—Boil a little nut gall and add to the water. If it turns gray or slate, black iron is present. 2d.—Dissolve a little prussiate of potash, and if iron is present it will turn blue.

Test for Lime.—Into a glass of the water put two drops of oxalic acid and blow upon it, if it gets milky, lime is present.

Test for Acid.—Take a piece of litmus paper. If it turns red there must be acid. If it precipitates on adding lime water it is carbonic acid. If a blue sugar paper is turned red it is a mineral acid.

Am. Gas Light Journal.

THE TRANSMISSION OF POWER BY VARIOUS SYSTEMS.

COST FOR 100 H. P. FOR GIVEN DISTANCES.

SYSTEMS EMPLOYED.	FEET.						MOTOR.
	330	1640	3280	16400	32810	65620	
	cts.	cts.	cts.	cts.	cts.	cts.	
Electricity	3.60	3.68	3.88	4.54	5.68	9.22	Steam.
Water pressure . .	4.54	4.73	5.22	8.06	11.58	19.14	
Compressed air . .	6.34	6.46	6.66	8.10	10.50	12.78	
Ropes	2.52	2.98	3.16	5.76	8.58	25.36	
Electricity	.92	.96	1.06	1.24	1.36	2.30	Hydraulic.
Water pressure . .	.92	1.10	1.24	2.66	4.46	7.08	
Compressed air . .	1.44	1.60	1.68	2.42	3.72	6.72	
Ropes	.50	.54	.60	1.60	2.84	6.78	

Cost of Electricity probably estimated.

STRENGTH OF ROPES IN TONS.

Multiply the square of the circumference by 0.2 for hemp, 1.5 for iron wire and 2.5 for steel wire.

TRANSMISSION OF POWER BY BELTS.

With flat leather belts, single thickness, connecting directly iron pulleys of equal diam., and therefore in contact with one-half of the circumference of both pulleys, the power transmitted may be taken as one horse power for each 70 square ft. of belt per minute.

The power is not materially affected by the diameter of the pulleys, unless they are very small in proportion to the power, but is affected by the proportion of their circumference enwrapped.

Taking the power transmitted when the belt makes half a coil around the pulley as 1, the power for other proportions of contact are :

Coll.....	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	1
Power.....	.63	.84	.92	1.	1.07	1.125	1.22	1.35

When the coil on the two pulleys is unequal, the one having the least, of course, determines the power transmitted. For double belt the power will be increased about 75 per cent.

CEMENTS FOR IRON.

Cement which resists heat and water, lime 10 parts, iron filings 5 parts, vinegar 2 parts, water 3 parts.

CEMENT FOR OBJECTS WHICH HAVE TO BE HEATED.

Iron filings 100 parts, fire clay 50 parts, common salt 10 parts, quartz sand 20 parts.

CEMENT FOR UNION OF IRON AND STONE.

Fine iron filings 10 parts, plaster of Paris 30 parts, sal. ammonia one-half. Mix to a fluid paste with weak vinegar; use at once.

CEMENT FOR IRON TANKS.

Finest iron filings are mixed with vinegar into a paste, left to stand until it becomes brown. The mass to be pressed into the joints.

FIRE-PROOF CEMENT FOR IRON PIPES.

Wrought iron filings 45 parts, clay 20 parts, china clay 15 parts, common salt solution 8 parts. Fire clay may be used instead of china clay.

AMMONIAC IRON CEMENT.

Iron filings 100 parts, sal-ammonia 2 parts, water 10 parts. Begins to rust after a few days and becomes very strong, and proof against water and steam.

CEMENT FOR BROKEN IRON VESSELS.

Iron filings 10 parts, clay 60 parts ; mixed with with linseed oil into a thick paste, thinned when used with same, and left to dry slowly.

RUST CEMENT FOR IRON.

Wrought iron filings 65 parts, sal-ammonia $2\frac{1}{2}$ parts, sulphur (flowers) $1\frac{1}{2}$ parts, sulphuric acid 1 part. Solid ingredients mixed dry. Sulphuric acid diluted with sufficient water then added. Dries in two or three days, and unites with the iron, making a resisting and solid mass.

CEMENTS FOR FILLING FAULTS IN IRON CASTINGS.

Iron filings free from rust 10 parts, sulphur $\frac{1}{2}$ part, sal-ammonia 0.8 parts. Mixed with water to a thick paste, which is rammed into the fault. Becomes strong when rusted. The parts to be cemented to be treated before the operation with liquid ammonia so as to free them from grease.

FIRE CLAY CEMENT.

1.—Iron filings 140 parts, hydraulic lime 25 parts, quartz sand 25 parts, sal-ammonia 3 parts. Formed into a paste with vinegar.

2.—Iron filings 180 parts, lime 45 parts, common salt 8 parts. Worked into a paste with strong vinegar. Must be perfectly dry before heating.

The *American Engineer* calls attention to a cement which, if made in accordance with the plan proposed, that authority claims will resist the advances of sulphuric acid, made even at a boiling heat. Melt caoutchouc at a gentle heat, and stir in from six to eight per cent. of tallow. Then mix in enough dry slacked lime

to make the whole the consistency of soft paste, after which add about 25 per cent. of red lead, which causes the mass to set hard and dry. A mixture of caoutchouc in twice its weight of linseed oil, and the addition of an equal amount of pipe clay, will form a paste that will resist the action of most acids.

CAST IRON.

Cast iron shrinks in cooling about $\frac{1}{4}$ inch per foot.

The weight of a casting will be about 16 times the weight of a pattern in pine.

Cast iron will last for a long time without rusting if the outer surface is not injured, as it is coated with a film of the protoxide of iron, produced by the action of the sand of the mould on the iron.

Cast iron rusts more rapidly when partly wet and partly dry, than when wholly immersed in water, or wholly exposed to the air.

The character of cast iron may be judged by the nature of the fracture

If lusterless and of dark color, friable and weak.

If uniform gray, with high metallic lustre, tough.

If light gray, with high metallic lustre, hard, stiff iron.

If light gray, without lustre, hard and brittle.

If very light gray, with radiating crystals, very hard and brittle.

TABLE OF USEFUL DATA.

ARRANGED ALPHABETICALLY.

Air.—Specific gravity, 0.0012 Weight of a cubic ft., 0.0753 lbs. or 527 grains. 13.3 cubic ft. of air weigh 1 lb.: it expands $\frac{1}{480}$ or .00208 of its bulk at 32 F. by the addition of 1 degree of heat.

Atmosphere.—The pressure of the atmosphere is usually estimated at 30 ins. of mercury, which is very nearly $14\frac{3}{4}$ lbs. upon a square inch, and equivalent to a column of water 34 ft. high.

Brass, cast.—Specific gravity 8.37, weight of a cubic ft. 523 lbs. Weight of a bar 1 ft. long and 1 in. square, 3.63 lbs., melts at 1.869 F. Cohesive force of a square inch, 18000 lbs.

Brick.—Specific gravity, 1.841 ; weight of a cubic ft. 115 lbs. Absorbs $\frac{1}{8}$ of its weight of water ; cohesive force per square inch 275 lbs. ; is crushed by a force of 562 lbs. on a square inch.

Bridges.—When an ordinary road bridge is covered with people it is about equivalent to a load of 120 lbs. on a square foot.

Cast Iron.—Specific gravity, 7.207 ; weight of a cubic ft. 450 lbs. A bar 1 ft. long and 1 in. square, weighs 3.2 lbs. nearly. ; melts at 3,479° F., and shrinks in cooling from $\frac{1}{8}$ to $\frac{1}{16}$ of its length ; is crushed by a force of 98,000 lbs. upon a square inch.

Coal, Newcastle.—Specific gravity, 1.269 ; weight of a cubic ft. 79.31 lbs. A London chaldron of 36 bushels weighs about 28 cwt. A Newcastle chaldron is 58 cwt.

Obpper.—Specific gravity, 8.75 ; weight of a cubic ft. , 549 lbs. Weight of a bar 1 ft. long and 1 in. square, 3.81 lbs.

Earth, common.—Specific gravity, 1.52 to 2.00 ; weight of a cubic ft. from 95 to 125 lbs.

Gravel.—Weight of a cubic ft. about 120 lbs.

Gun-metal, cast.—(Copper 8 parts, tin 1.) Specific gravity 8.153 ; weight of a cubic ft., 509.5 lbs. Weight of a bar 1 ft. long and 1 in. square, 3.54 lbs.

Horse—Of average power produces the greatest effect in drawing a load when exerting a force of 187.5 lbs., with a velocity of 2 $\frac{1}{4}$ ft. per second, working 8 hours per day. A good horse can exert a force of 480 lbs. for a short time. In calculating the strength for horse machinery the horse's power should be considered 400 lbs.

Iron, malleable.—Specific gravity, 7.6 ; weight of a cubic ft. 475 lbs. Weight of a bar 1 ft. long and 1 in. square, 3.8 lbs.

Lead, cast.—Specific gravity, 11.353 ; weight of a cubic ft 709.05 lbs. Weight of a bar 1 ft. long and 1 in. square, 4.94 lbs. ; melts at 612° F.

Man.—A man of average power produces the greatest effect when exerting a force of 31 $\frac{1}{4}$ lbs., with a velocity of 2 ft. per second for 10 hours per day. A strong man will raise and carry from 250 to 300 lbs.

Marble, white.—Specific gravity, 2.706; weight of a cubic ft. 169 lbs. Cohesive force of a square in. 1.811 lbs.

Steam.—Specific gravity at 212° F. is to that of air at the mean temperature, as 0.472 is to 1. Weight of a cubic ft. 249 grains.

Steel.—Specific gravity, 7.84; weight of a cubic ft. 490 lbs. Cohesive force of a square in. 130,000 lbs.

Tin, cast.—Specific gravity 7.291. Weight of a cubic ft. 455.7 lbs. Melts at 442° F.

Water, river.—Specific gravity, 1,000; weight of a cubic ft. 62.5 lbs. Weight of a cubic in., 252.525 grains. Expands in freezing $\frac{1}{17}$ th of its bulk, and the expanding force of freezing water is about 35,000 lbs. per square in. Sea water has a specific gravity 1.0271. Weight of a cubic ft. 64.2 lbs. Water is 828 times the density of air at 60° F. and Bar. 30°

Wind.—Greatest observed velocity 159 feet per second; force with that velocity about 57.75 lbs. on a square ft.

Zinc, cast.—Specific gravity 7.028; weight of a cubic ft. 439.25 lbs. Melts at 648° F.

EPITOME OF CHEMISTRY.

Chemistry treats of the composition of bodies and the specific properties of matter.

EXAMPLES.—Water is composed of two gases, hydrogen and oxygen; gold is yellow.

Organic Chemistry deals with those substances which have been produced by life, as flesh and wood.

Inorganic Chemistry is confined to those which have not been formed by life, as sand, glass, metals.

An Element is a kind of matter which has never been separated into other substances, as gold, iron, etc. Sixty-four elements are now known, fifty-one of which are considered to be metals, and thirteen non-metals.

A *Compound* substance is one composed of two or more elements, as water H_2O , carbonic acid gas CO_2 , etc. Compounds, in their properties, are in general, very unlike their elements.—Examples :—Yellow sulphur and white quicksilver form red vermillion; inert charcoal, hydrogen and nitrogen produce the deadly prussic acid; poisonous and offensive chlorine combines with the brilliant metal sodium to form common salt.

• The elements have no more likeness to the compounds which they form, than the separate letters of the alphabet, have to the words which may be made from them.—MILLER.

Chemical Affinity is that force which causes the elements of matter to unite and form new compounds. It acts upon the most dissimilar substances, the more unlike the stronger the union.

Nomenclature.—The elements which were known anciently retain their former names. Others are named from some peculiarity, as chlorine from its green color, bromine from its bad odor.

Atomic weight—The atomic weight of an element expresses the proportion by weight in which it unites with other elements. Hydrogen is taken as the unit of atomic weight.

All bodies are considered to be collections of molecules, as molecules are of atoms.

The molecule of a compound always contains two or more atoms. The molecule may be destroyed, but the atom is indestructible.

The specific properties of a substance reside in the molecule, and to destroy the molecule is to destroy the substance.

A chemical change consists in a rearrangement of the atoms and the formation of new molecules, and hence of new properties.

A *Binary* compound is a union of two elements, as sodium and chlorine $NaCl$. sodium chloride, CO . carbonic oxide.

One atom of oxygen in a molecule forms the monoxide or protoxide, two the dioxide or binoxide, three of oxygen and two of the other element, the sesquioxide (meaning $1\frac{1}{2}$) and the highest number the peroxide.

The terminations "ic" and "ous" are used for acids.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases they are said to be hydrated.

1.—Each element is composed of indivisible atoms which are exactly equal in size and weight.

2.—The *atomic weights* represent the relative weights of the atoms of various kinds.

3.—Compounds are formed by the union of atoms of different kinds in the proportion of their atomic weights or multiples of them.

The molecular weight of a compound is equal to the sum of the atomic weights of its elements.

The above four statements are the bases of the *Atomic Theory* as now understood.

MATHEMATICS OF CHEMISTRY—The beauty of the divine law of harmony is nowhere seen so clearly as in the law of atomic weights. In the fourth principle of the atomic theory we see that the atomic weight of any element in a compound, divided by the molecular weight of that compound, is the proportion of that element contained in it. Example.—The atomic weight of Hydrogen is 1, of Oxygen 16; the molecular weight of water is therefore $H_2O = 2 + 16 = 18$, hence, the proportion of H is $\frac{2}{18}$ or $\frac{1}{9}$, and of O $\frac{16}{18}$ or $\frac{8}{9}$. In 10 lbs. of H_2O there are therefore $10 \times \frac{2}{18}$ or $8\frac{2}{9}$ lbs. of O, and $10 \times \frac{1}{9}$ or $1\frac{1}{9}$ lbs. of H.

A chemical change is called a *reaction*. Example—Water added to lime forms hydrate of lime, or *slacked lime*, and is expressed thus, $H_2O + CaO = CaOH_2$.

The *quantivalence* of an element is its power of combining with Hydrogen. If we examine the compounds HCl , H_2O , H_3N , and H_4C we find the molecule of each has respectively 1, 2, 3, 4 atoms of H, and we see that the elements Cl, O, N and C have different powers of combination whereby they can unite with a different number of H atoms. The same principle holds throughout all the elements. They are therefore divided into classes according to their powers of combining with H, and are given names expressing that power. Each atom is supposed to have a certain number of poles or combining points by which it holds or becomes united to other atoms. Hydrogen H, Chlorine Cl and Sodium Na have but one combining point, and they can therefore only unite

in pairs. Oxygen has two combining points, and can therefore take two atoms of H as in H_2O . Carbon C has four combining points, and can therefore take 4 atoms of H or any other monad, as in $C H_4$, marsh gas where one atom of carbon C is combined with four atoms of Hydrogen H.

The elements are therefore called according to their number of combining points, monads, dyads, triads, tetrads, pentads and hexads. In the table of the elements the quantivalence of each element is given. The quantivalence of some of the elements is disputed, and therefore both are given.

It sometimes happens that an element cannot get other elements to take up all its points. In this case it is supposed that the vacant points or poles absorb each other; an example of this is CO carbonic oxide. Carbon being a tetrad, and Oxygen a dyad, two of the carbon points are unabsorbed.

The quantivalence of the elements, and their supposed combination with each other, can be shown more clearly by the use of the geometrical symbols invented by Mr. Wm. Farmer.*

In this system the Univalent Elements or Monads are represented by the symbol.



“ Bivalent Elements or Dyads are represented by the symbol.



“ Trivalent Elements or Triads are represented by the symbol.



“ Quadrivalent Elements or Tetrads are represented by the symbol.



“ Quinivalent Elements or Pentads are represented by the symbol.



“ Sexivalent Elements or Hexads are represented by the symbol.



* The CHEMISTS' AND STUDENTS' ASSISTANT for teaching chemistry to younger students, published by Wm. Farmer, pamphlet and blocks. A system by which the Elements and their Valences are represented by illustration and solid bodies.

These symbols, however, would make a book of this kind too bulky, therefore but a few reactions can be illustrated by this system.

A molecule of Hydrogen H_2 , two atoms of H.

“ “ “ Chloride of sodium Na. Cl. One atom
of Na. and one of Cl.

“ “ “ Oxygen O_2 , two atoms of oxygen.

“ “ “ Calcic oxide, one atom of Calcium Ca.
and one of O.

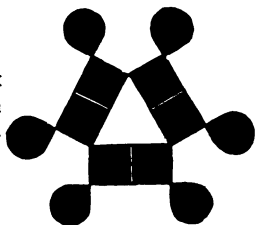
“ “ “ Water H_2O , one atom of Oxygen
O and two of Hydrogen H.

“ “ “ Carbonic oxide CO, one atom of Carbon
C and one of Oxygen O.

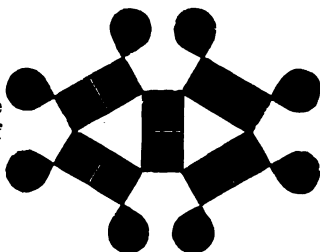
“ “ “ Carbonic acid gas CO_2 , one atom of C
and two of O.

“ “ “ Marsh gas CH_4 , one atom of
Carbon C and four of Hy-
drogen H.

A molecule of Benzine C_6H_6 , six atoms of Carbon **C** and six of Hydrogen **H**.

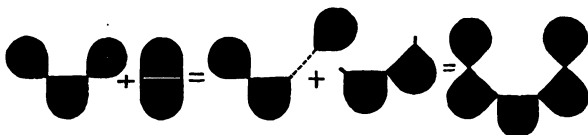


A molecule of Naphthaline $C_{10}H_8$, ten atoms of **C** and 8 of **H**.



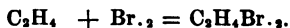
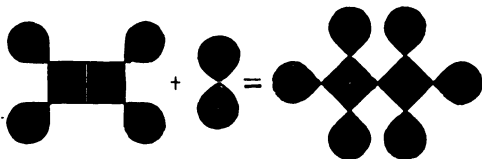
Reactions are shown as follows :

Water and Calcic Oxide Converted into Calcic Hydrate.



Water + Calcic Oxide = Calcic Hydrate.

Ethene and Bromine converted into Ethene di-bromide.



Ethene + Bromine = Ethene di-bromide.

Hydrocarbons, or combinations of Hydrogen and Carbon are classed in series, according to the proportions of each of the above elements contained in them.

These series may be shown more clearly in the following table. It will be noticed that in each series the number of atoms of each element increase in a certain ratio, thus in the Paraffin series the symbol of the series is $C_n H_{2n} + 2$, which means that every one of this series from CH_4 up to $C^{10} H^{22}$ has twice the number of Carbon atoms + 2 of Hydrogen; thus CH_4 is composed of $1C + 2H + 2$ and $C_{10} H_{22}$ is composed of $10C + 20H + 2$.

HYDRO-CARBON SERIES AND SYMBOLS.

1—Paraffin series.....	$C_n H_{2n} + 2$	.. CH_4	to $C_{10} H_{22}$
2—Olefine “	$C_n H_{2n}$	.. CH_2	to $C_{10} H_{20}$
3—Acetylene “	$C_n H_{2n} - 2$	.. $C_2 H_2$	to $C_{10} H_{18}$
4—Terpene “	$C_n H_{2n} - 4$	.. $C_5 H_8$	to $C_{10} H_{16}$
5—Benzene “	$C_n H_{2n} - 6$	.. $C_6 H_6$	to $C_{12} H_{12}$
6—Cinnamene“	$C_n H_{2n} - 8$	.. $C_8 H_8$	to $C_{10} H_{12}$
7—Phenyl-acetylene series....	$C_n H_{2n} - 10$	.. $C_8 H_6$	
8—Naphthalene “	$C_n H_{2n} - 12$	.. $C_{10} H_8$	to $C_{14} H_{10}$
9—Diphenyl “ ...	$C_n H_{2n} - 14$	.. $C_{12} H_{10}$	to $C_{18} H_{14}$
10—Stillbene “	$C_n H_{2n} - 16$	.. $C_{12} H_8$	to $C_{20} H_{16}$
11—Anthracene “	$C_n H_{2n} - 18$	.. $C_{14} H_{10}$	to $C_{18} H_{14}$
12—Benzyl. naphthalene series	$C_n H_{2n} - 20$	.. $C_{17} H_{14}$	
13—Pyrene series.....	$C_n H_{2n} - 22$	.. $C_{16} H_{10}$	to $C_{21} H_{16}$
14—Chrysene “	$C_n H_{2n} - 24$	.. $C_{18} H_{12}$	to $C_{19} H_{14}$
15—Di-naphtyl series.....	$C_n H_{2n} - 26$	.. $C_{20} H_{14}$	to $C_{21} H_{16}$
16—Di-naphtyl ethylene series	$C_n H_{2n} - 28$	.. $C_{22} H_{16}$	
17—Idrialene series.....	$C_n H_{2n} - 30$	.. $C_{22} H_{14}$	to $C_{26} H_{22}$
18—Tetra-phenyl-ethylene ser..	$C_n H_{2n} - 32$	.. $C_{26} H_{20}$	

As the proportion of carbon increases the Hydro-carbons change from gaseous to a liquid and finally to a solid form.

TABLE OF THE ELEMENTS.

WITH THEIR SYMBOLS, ATOMIC AND MOLECULAR WEIGHT,
SPECIFIC GRAVITY AND QUANTIVALENCE.

	Symbol	Atomic Weight	Molecular Weight.	Specific Gravity	Quantivalence.
Aluminium	Al.	27.5	$Al_3 = 55$	2.67	II or IV
Antimony (Stibium)....	Sb.	122	$Sb_4 = 488$	6.71	III or V
Arsenic	As.	75	$As_4 = 300$	5.95	III or V
Barium	Ba.	137	$Ba_2 = 274$	1.85	II
Bismuth	Bi.	210	$Bi_4 = 840$	9.799	III or V
Boron	B.	11	.....	2.680	III
Bromine	Br.	80	$Br_2 = 160$	3.187	I
Cadmium	Cd.	112	$Cd_2 = 224$	8.604	II
Caesium	Cs.	133	$Cs_2 = 266$	unkn'wn	I
Calcium	Ca.	40	$Ca_2 = 80$	1.578	II
Carbon	C.	12	$C_2 = 24$	2.35	IV
Cerium	Ce.	92	.....	.....	II
Chlorine	Cl.	35.5	$Cl_2 = 71$	2.435	I
Chromium	Cr.	52.5	$Cr_2 = 105$	6.810	II or IV
Cobalt	Co.	59	$Co_2 = 118$	8.95	II
Copper (Cuprum)	Cu.	63.5	$Cu_2 = 127$	8.90	II
Didymium	D.	96	$D_2 = 192$	.....	II
Erbium	E.	112	$E_2 = 224$	.....	II
Fluorine	F.	19	$F_2 = 38$	1.31	I
Gallium	Ga.	.....	.....	4.7	.....
Glucinium	G.	9.5	$G_2 = 19$	2.10	II
Gold (Aurum)	Au.	197	$Au_2 = 394$	19.34	III
Hydrogen	H.	1	$H_2 = 2$	.069	I
Indium	In.	76	.....	7.20	II
Iodine	I.	127	$I_2 = 254$	4.94	I
Iridium	Ir.	197	.....	21.80	II or IV
Iron (Ferrum)	Fe.	56	.....	7.80	II or IV
Lanthanum	La.	92	.....	.....	II
Lead (Plumbum)	Pb.	207	.....	11.36	II
Lithium	L.	7	$L_2 = 14$	0.59	I
Magnesium	Mg.	24	.....	1.70	II
Manganese	Mn.	55	.....	8.00	II or IV
Mercury (Hydrargyrum)	Hg.	200	.....	13.596	II
Molybdenum	Mo.	96	.....	8.64	VI
Nickel	Ni.	59	.....	8.90	II
Niobrium	Nb.	94	.....	.....	V
Nitrogen	N.	14	$N_2 = 28$	.971	III or V
Osmium	Os.	19.9	.....	21.40	II or IV
Oxygen	O.	16	$O_2 = 32$	1.1056	II
Palladium	Pd.	106	.....	11-12	II or IV
Phosphorus	P.	31	.....	1.83	III or V

TABLE OF THE ELEMENTS. (*Continued*)

WITH THEIR SYMBOLS, ATOMIC AND MOLECULAR WEIGHT,
SPECIFIC GRAVITY AND QUANTIVALENCE.

	Symbol	Atomic Weight	Molecular Weight.	Specific Gravity	Quantivalence.
Platinum.....	Pt	197	.....	21.53	II or IV
Potassium (Kalium)...	K.	39	$K_2 = 78$	.865	I
Rhodium.....	Ro.	104	.....	11.00	II or IV
Rubidium.....	Rb.	85	$Rb_2 = 170$	1.52	I
Ruthenium.....	Ru.	104	.....	11-12	II or IV
<i>Selenium</i>	Se.	79.5	$Se_2 = 159$	4.80	II or VI
<i>Silicon</i>	Si.	28	.....	2.49	IV
Silver (Argentum).....	Ag.	108	$Ag_2 = 216$	10.50	I
Sodium (Natrium).....	Na.	23	$N_2 = 46$	.972	I
Strontium.....	Sr.	87.5	.....	2.54	II
<i>Sulphur</i>	S.	32	$S_2 = 64$	2.00	II or VI
Tantalum.....	Ta.	182	.....	10.78	V
<i>Tellurium</i>	Te.	129	$Te_2 = 258$	6.65	II or VI
Thallium.....	Tl.	204	.....	11.86	I or III
Thorium.....	Th.	238	.....	.....	IV
Tin (Stennum).....	Tn.	118	.....	7.3	II or IV
Titanium.....	Ti.	50	.....	53	II or IV
Tungsten (Wolfranium)	W.	184	.....	17.50	VI
Uranium.....	U.	120	.....	18.40	III or V
Vanadium.....	V.	51	.....	3.64	III or V
Yttrium.....	Y.	62	.....	.....	II
Zinc.....	Zn.	65	.....	7.15	II
Zirconium.....	Zr.	89	.....	4.15	IV

NOTE.—The names of metals are printed in Roman, non-metals in *italics*.

NAMES OF CHEMICALS

ACCORDING TO THE OLD AND THE NEW NOMENCLATURE.

The Old.	Symbol.	The New.
Aqua Fortis.....	HNO_3	Nitric Acid.....
Aqua Regia.....	HCl. HNO_3	Nitro-Muriatic Acid....
Blue Vitriol.....	$\text{Cu SO}_4 \cdot 5\text{H}_2\text{O}$	Sulphate of Copper.....
Calomel.....	Hg Cl.	Chloride of Mercury.....
Carbonate Calcium.....	Ca CO_3	Chalk.....
Carbonate of Potassa..	K_2CO_3	Potassium Carbonate...
Caustic Potash.....	$2(\text{KHO})$	Hydrate Potassium.....
Chloroform.....	CH. Cl_3	Chloride of Formyl.....
Common Salt.....	Na Cl.	Chloride of Sodium.....
Copperas.....	$\text{Fe SO}_4 \cdot 7\text{H}_2\text{O}$	Sulphate of Iron.....
Corrosive Sublimate...	Hg. Cl_2	Bi-Chloride of Mercury..
Diamond.....	C.	Pure Carbon.....
Dry Alum.....	.....	Sulph Allum. and Potas.
Epsom Salts.....	$\text{Mg. SO}_4 \cdot 7\text{H}_2\text{O}$	Sulphate of Magnesia....
Ethiops Mineral.....	.....	Black Sulph. of Mercury
Fire Damp, Marsh Gas..	CH_4	Light Carburetted Hydrog.
Galena, Lead Ore.....	Pb. S	Sulphide of Lead.....
Glauber's Salts.....	$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$	Sulphate of Sodium.....
Glucose.....	$\text{C}_6\text{H}_{12}\text{O}_6$	Grape Sugar.....
Gouldar Water.....	.....	Basic Acetate of Lead...
Hydriodic.....	HI	Hydrogen and Iodine....
Iron Pyrites, fool's gold	Fe S_2	Bi-Sulphuret of Iron...
Jewellers Putty.....	Sn O	Oxide of Tin.....
Kingo Yellow.....	.....	Sulphide of Arsenic.....
Laughing Gas.....	N_2O	Protoxide of Nitrogen...
Lime.....	Ca O	Oxide of Calcium.....
Lunar Caustic.....	Ag NO_3	Nitrate of Silver.....
Muriate of Lime.....	Ca Cl.	Chloride of Calcium....
Oil of Vitriol.....	H_2SO_4	Sulphuric Acid.....
Potash.....	K_2O	Oxide of Potassium.....
Red Lead.....	Pb O_2	" " Lead.....
Rust of Iron.....	Fe O	" " Iron.....
Salammoniac.....	H_4NCL	Muriate of Ammonia....
Soda.....	HNa CO_3	Oxide of Sodium.....
Spirits of Hartshorn...	NH_3	Ammonia.....
Stucco, or plaster of paris	$\text{Ca SO}_4 \cdot 2\text{H}_2\text{O}$	Sulphate of Lime.....
Sugar of Lead.....	.....	Acetate of Lead.....
Verdigris.....	Cu O	Basic Acetate of Copper.
Vermillion.....	Hg S	Sulphide of Mercury.....
Vinegar.....	$\text{C}_4\text{H}_4\text{O}_2$	Acetic Acid (diluted)....
Water.....	H_2O	Oxide of Hydrogen.....
White Precipitate.....	Zn SO_4	Sulphate of Zinc.....

A TABLE OF SOME OF THE ELEMENTS AND COMPOUNDS.

WITH THEIR COMBINING WEIGHTS, VOLUMES AND SPECIFIC GRAVITIES *

	Combining Weight.	Cubic Ft. per pd.	Cubic Feet per com- bu' g w'gt.	Specific Gravity, Air = 1.
Hydrogen (H ₂).....	2.00	188.53	377.07	0.0692
Carbon Vapor (C ₂).....	23.94	15.75	377.07	0.8292
Nitrogen (N ₂).....	28.06	13.43	377.07	0.9719
Oxygen (O ₂).....	31.92	11.81	377.07	1.1056
Chlorine (Cl ₂) ..	71.00	5.81	377.07	2.4593
Bromine (Br ₂).....	160.00	2.35	377.07	5.5420
Flourine (F ₂).....	38.00	9.92	377.07	1.3162
Iodine (I ₂).....	253.20	1.48	377.07	8.7703
Sulphur (S ₂).....	63.96	5.89	377.07	2.2154
Phosphorus (P ₄).....	123.84	3.04	377.07	4.2895
Carbonic oxide (CO).....	27.93	13.50	377.07	0.9674
Carbonic acid (CO ₂).....	43.89	8.59	377.07	1.5202
Water vapor (H ₂ O).....	17.96	20.90	377.07	0.6221
Hydro sulphide (H ₂ S).....	33.98	11.09	377.07	1.1770
Ammonia (H ₃ N).....	17.03	22.14	377.07	0.5898
Sulphurous oxide (S ₂ O).....	63.90	5.9	377.07	2.2133
Sulphuric oxide (SO ₂)	79.86	4.72	377.07	2.7662
Cyanogen (C ₂ N ₂).....	52.00	7.25	377.07	1.8011
Bisulphide of carbon (CS ₂)..	75.93	4.96	377.07	2.6300
Ethyl alcohol (C ₂ H ₅ O).....	45.90	8.21	377.07	1.5898
Ethyl ether (C ₄ H ₁₀ O).....	73.84	5.10	377.07	2.5576
Methyl alcohol (CH ₃ O)....	31.93	11.81	377.07	1.1059
Methyl chloride (CH ₃ Cl)....	50.47	7.47	377.07	1.7482
Carbonyl chloride (COCl ₂)..	98.93	3.81	377.07	3.4267
Phosphine gas (PH ₃).....	33.96	11.10	377.07	1.1763
Hydrochloric acid (HCl)....	36.50	10.33	377.07	1.2642
Methane (CH ₄)	15.97	23.61	377.07	0.5531
Ethane (C ₂ H ₆).....	29.94	12.59	377.07	1.0370
Propane (C ₃ H ₈).....	43.91	8.58	377.07	1.5209
Butane (C ₄ H ₁₀).....	57.88	6.51	377.07	2.0048
Ethane (C ₂ H ₆).....	27.94	13.49	377.07	0.9677
Propene (C ₃ H ₆).....	41.91	8.99	377.07	1.4516
Butene (C ₄ H ₈).....	55.88	6.74	377.07	1.9355
Ethine (C ₂ H ₂).....	25.94	14.53	377.07	0.8985
Propine (C ₃ H ₄).....	39.91	9.44	377.07	1.3824
Butine (C ₄ H ₆).....	53.88	6.99	377.07	1.8662
Quintone (C ₅ H ₈).....	65.85	5.72	377.07	2.2809
Benzene (C ₆ H ₆).....	77.82	4.84	377.07	2.6955
Styrolene (C ₈ H ₈)	103.75	3.63	377.07	3.5936
Naphthalene (C ₁₀ H ₈)	127.76	2.95	377.07	4.4282
Turpentine (C ₁₀ H ₁₆).....	135.70	2.77	377.07	4.7003
Dry Air.....	28.87	13.06	.....	1.0000

*A paper read before the Society of Gas Lighting, by Wm. Farmer.

When the combining weight of any of these Elements and Compounds is taken in pounds, then the gas or vapor therefrom will always occupy about 377.07 cubic feet of space at 60° F and 30 inches barometer.

If we divide this constant, 377.07, by the combining weight of any of the substances then the quotient will be the number of cubic feet per pound of the same.

If we divide the combining weight of any of the substances given in the table by 2, then the quotient will give the density of the same as compared with Hydrogen.

If we divide the combining weight of any of the substances by the constant 28.87, then the quotient will be the specific gravity of the gas or vapor therefrom as compared with air.

All the calculations are based on the atomic weights which are now generally adopted by the majority of chemists.

OXYGEN O.

Oxygen is the most abundant of all the elements, comprising by weight $\frac{1}{5}$ of the air, $\frac{8}{100}$ of the water, $\frac{2}{3}$ of all animal bodies, and about $\frac{1}{4}$ of the crust of the earth. It has no odor, color, or taste. It combines with nearly every element.

Its union with a substance is called *oxidation*, and the product an *oxide*. It is a vigorous supporter of combustion.

All ordinary processes of fermentation, decay putrefaction and fire are produced by a union of Oxygen with a substance, and are only different forms of oxidation. If Oxygen unites rapidly we call it fire; if slowly, decay. Yet the process and the products are the same. Each adult uses daily $1\frac{1}{2}$ lbs. of Oxygen. The consumption of 1 lb. of coal requires $2\frac{2}{3}$ lbs.

HYDROGEN.

Hydrogen was discovered in 1776. It constitutes 11 per cent. by weight of water; it also occupies an important place in the composition of nearly all organic substances. It is a permanent gas, colorless, transparent and if pure, odorless. It is the lightest of all known substances, and is consequently used as the unit of comparison of the specific gravity of gases. Its weight compared with air as 1,000 is .0691.

The combustion of hydrogen and oxygen is accompanied by the most intense heat that can be produced. If the mixed gases are allowed to issue under pressure from a jet, and inflamed, the heat produced by the combustion is sufficiently powerful to melt platinum and pipe clay, which substances resist the heat of all furnaces. The flame of this jet of mixed gases, (generally termed the *oxyhydrogen blow pipe jet*) is very pale, but becomes dazzlingly bright when a solid infusible substance is introduced into it. If the flame is allowed to fall on a pencil of lime, a most intense light is obtained, which is known as the lime light, and is used extensively in theatrical illumination and in stereoptican exhibitions.

NITROGEN.

Nitrogen was discovered in 1772. The atmosphere contains about 77 per cent. by weight of nitrogen, and 79 per cent. by volume. It is a permanent gas, devoid of color, taste or smell, and not possessing any active properties. It is incombustible, and does not support combustion; it consequently will not support respiration. It is however not poisonous in its properties, since when mixed with oxygen it may be breathed with impunity. $\frac{4}{5}$ ths of the bulk of the atmosphere consists of nitrogen.

The most noted compounds of nitrogen are those which it forms with hydrogen and oxygen—the most important of the former being ammonia NH_3 , and of the latter nitric acid HNO_3 .

Nitrous oxide or laughing gas is a colorless gas, possessing a faint, sweet taste and smell. If breathed for a short time it produces a peculiar kind of intoxication, and if for a longer time insensibility.

CARBON C.

Carbon is one of the most abundant substances in nature, forming nearly one-half of the entire vegetable kingdom, and being a prominent constituent of limestone, corals, marble, &c.

It is found in three distinct forms, viz: the *diamond*, *graphite* and *amorphous carbon*. This last includes gas-carbon, charcoal, lamp-black, coal, coke, peat, soot, bone-black and ivory-black. In each of these various substances Carbon possesses different properties. Common charcoal can be turned into graphite, mineral coal into gas-carbon, and the diamond into coke. All of them, when heated in the open air, unite with the same quantity

of Oxygen, forming the same compound—carbonic anhydride— CO_2 , from which the Carbon can be obtained again in the form of charcoal.

The Diamond is pure Carbon crystallized. Its properties are too well known to admit of description here.

Graphite or *black-lead* or *plumbago* is supposed to be of vegetable origin.

Gas-carbon needs no description here. It is generally looked upon as a troublesome adjunct in the manufacture of illuminating gas from coal—but it compensates somewhat for the trouble it gives by filling up the pores and cracks in clay retorts. It gives out an intense heat when burned.

Carbon is the most unchangeable of all the elements. It is insoluble in any ordinary liquid. None of the acids, except nitric, corrodes it. No alkali will eat it. Neither air nor moisture affects it. A cubic inch of fine charcoal has, it is said, 100 ft. of surface, so full is it of minute pores. These absorb gases by capillary attraction to an almost incredible extent. A piece of Carbon will take up 90 times its bulk of Ammonia. At a high temperature the attraction of Carbon for Oxygen is powerful. In the heat of the furnace it will take it from the stablest compounds.

Nearly all the metals, and many of the other elements, are locked up in the rocks with Oxygen, and Carbon is the key made by the Creator for unlocking the treasure houses of nature.

Soot is unburnt Carbon, which passes off from a lamp or fire for want of Oxygen to combine with it.

Animal Charcoal or *bone-black* is made by burning bones in close vessels.

Mineral Coal. The formation of mineral coal is too vast a subject to be treated here.

Peat and Muck are imperfect kinds of coal.

CARBONIC OXIDE CO .

CO . Carbonic oxide is one of the constituents of both coal and water gas. It is colorless and almost odorless. It burns with a pale blue flame, absorbing an atom of oxygen from the air and becoming CO_2 . It is seen burning at the tops of flues in the retort house, and at the tops of tall chimneys.

When air enters at the bottom of a clear fire CO_2 is formed at once; but this gas passing up through the coal takes up a further

quantity of carbon becoming changed into CO thus $C + CO_2 = 2 CO$ the volume of the gas being exactly doubled in bulk, thereby. CO is a deadly poison, and escaping from coal-fires has often produced death.

Both CO and CO_2 leak through the pores of cast iron when heated. The offensive odor which comes out on opening the door of a coal stove is caused by the compounds of sulphur mixed with the CO.

CARBONIC ACID CO_2 .

Carbonic anhydride, commonly called carbonic acid, comprises 10.000 of the air, and is produced throughout nature in immense quantities. It is found combined with calcium in a large class of salts, known as the carbonates, viz: limestone, marble, chalk, etc., forming nearly one-half their weight, and almost one-seventh of the earth's crust. A bushel of charcoal in burning produces about 2500 gallons. A lighted candle gives off about four gallons per hour.

Each adult exhales daily about $8\frac{1}{2}$ oz. of carbon, changed to this invisible gas.

It is colorless, odorless and transparent; has a slightly acid taste, and is a non-supporter of combustion.

It is heavier than air, and can be poured from one dish to another, drawn off by a syphon, dipped up with a bucket like water, or weighed in a pair of scales like lead.

CO_2 is the deadly *choke damp* of the mines. It is produced by the combustion of *fire damp* CH_4 , which accumulates in deep mines, and when mixed with air, burns like gunpowder, forming dense volumes of CO_2 .

For experimental purposes CO_2 is prepared by pouring hydrochloric (muriatic) acid on marble dust or chalk. The reaction is as follows: $Ca CO_2 + 2 HCl = CO_2 + Ca Cl_2 + H_2 O$.

OXYGEN AND THE SUNBEAM.

Oxygen is the destroyer and the sunbeam the builder. Oxygen tears down every living structure, and would bring all things to rest in ashes. The sunbeam reinvigorates, rebuilds and rescues from the grasp of decay. Though they seem to be antagonists, oxygen and the sunbeam really work in harmony, and each supplements the labor of the other.—Death alone makes life possible.

—STEELE.

TABLE OF CHEMICAL CONSTANTS.

To find percentage of		in	Mul. by
Ammonia.....	NH ₃	Ammoniac Chloride.....	.31804
Baryta.....	Ba	Baric Sulphate.....	.65665
".....	Ba	Baric Carbonate.....	.77665
Calcium.....	Ca	Calcic Oxide (Lime).....	.71429
Calcic Oxide.....	CaO	Calcic Sulphate.....	.41176
".....	CaO	" Carbonate.....	.56000
Carbon.....	C	Carbonic Anhydride.....	.27273
Carbon Anhydride.....	CO ₂	Calcic Carbonate.....	.44000
Chlorine.....	Cl.	Argentio Chloride.....	.24724
Copper.....	Cu.	Cupreous Sulphide.....	.79849
Hydrogen.....	H	Water.....	.11111
Iron.....	Fe	Ferric Oxide.....	.70000
".....	Fe	Ferrous Sulphide.....	.63636
Lead.....	Pb.	Plumbic Oxide.....	.92825
".....	Pb.	" Sulphate.....	.68317
".....	Pb.	" Sulphide.....	.86610
Mercury.....	Hg.	Mercureous Oxide.....	.96231
Oxygen.....	O	Cupric Oxide.....	.20151
".....	O	Ferrous ".....	.22222
".....	O	Ferric ".....	.10000
".....	O	Plumbic ".....	.07175
".....	O	Calcic ".....	.28571
".....	O	Mercureous Oxide.....	.03846
".....	O	Potassic Oxide.....	.16982
Sulphur.....	S	Baric Sulphate.....	.13734
".....	S	Arsenious Sulphide.....	.89024
".....	S	Ferrum Sulphide.....	.38095

GAS.

The word "gas" was first used in the seventeenth century. Explosions, strange noises and lurid flames had been seen in mines, caves, &c. The alchemists (who were the only chemists of that day) whose earthen vessels often exploded with terrific violence commenced their experiments with prayer, and placed on their crucibles the sign of the cross—hence the name crucible from *crux* (gen. *crusis*) a cross. All these manifestations were supposed to be the work of invisible spirits to whom the name *gast* or *geist*, a ghost or spirit was applied. The miners were in special danger from these unseen adversaries, and it is said that their church service contained the petition, "From spirits, good Lord, deliver us!" The names "spirits of wine," "spirits of nitre," &c. are a relic of the superstitions of that time.

STEEL.

MAXIMS FOR GAS-MEN.

It is "false economy" to have cheap workmanship or materials anywhere around the works.

There is no room for "coal tar" in a purifying box.

Sweep snow off the holders as it falls.

Beer is not necessary in the manufacture of gas. Too much beer makes poor gas.

Steady heats are better than alternating ones.

Coal stored out of doors will make gas on its own account if not closely watched.

Benches fired up in a hurry will not be slow in cracking.

A good workman is known by his chips, so is a good superintendent known by the good condition of his works.

A careful superintendent will set a good example by not smoking around the works.

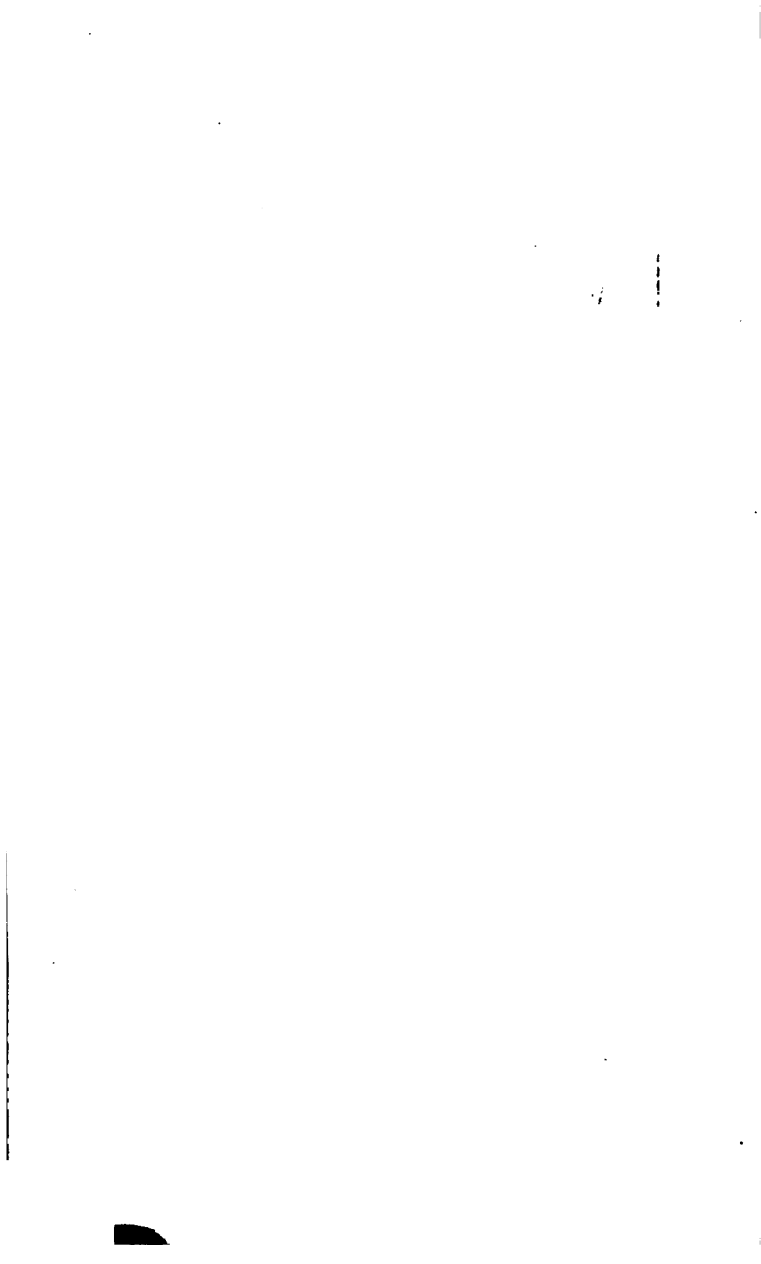
Money will be saved, and consequently earned, by a careful attention to the condition of the holders. Many small leaks are equal to one large one. A little paint will stop many small leaks.

It is poor economy to put in small services.

The purifying house should have a high, well ventilated and light cellar, with a coat of whitewash or white paint on everything.

The "fool-killer" is looking for the person who hunts gas leaks with a light.

The man who "didn't know it was loaded" is a near relation to the one who "blows out the gas."



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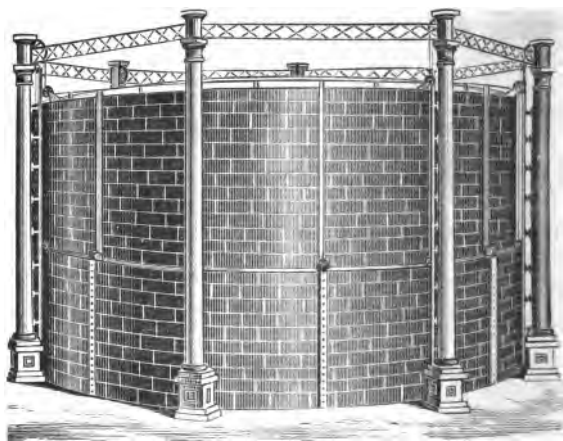
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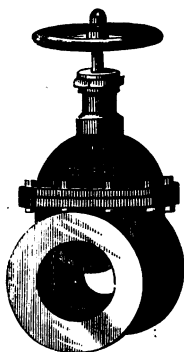
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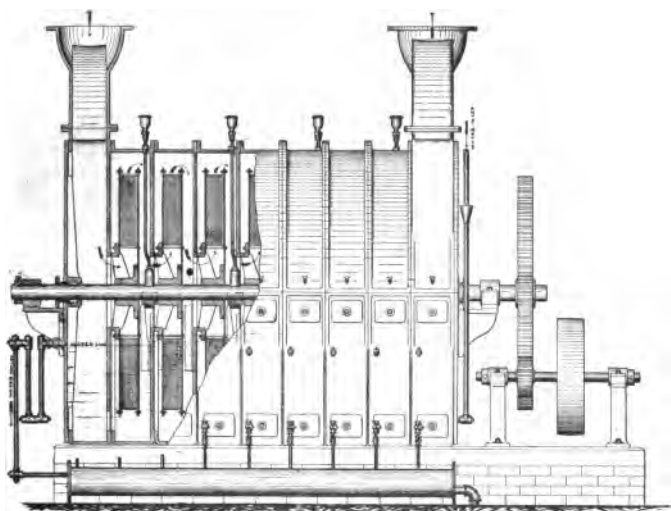
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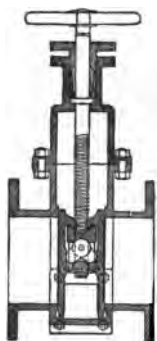
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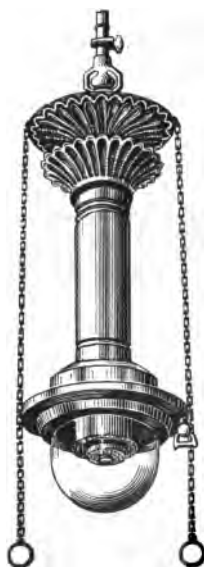
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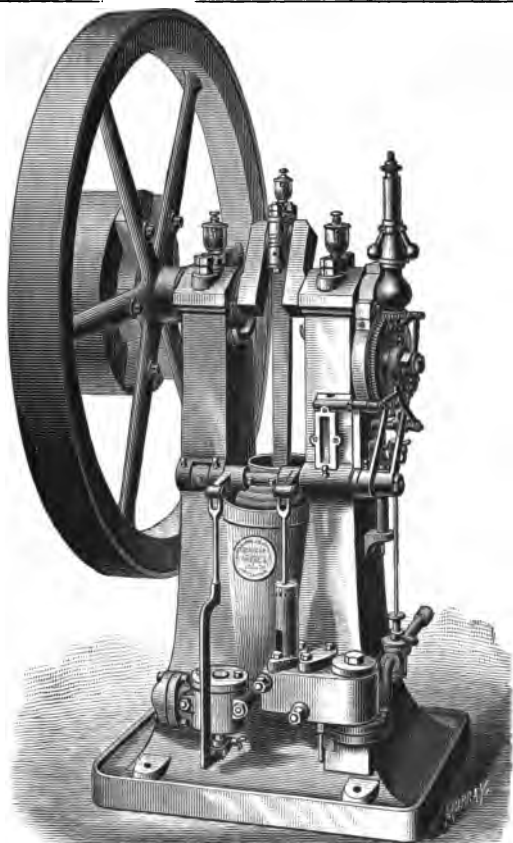
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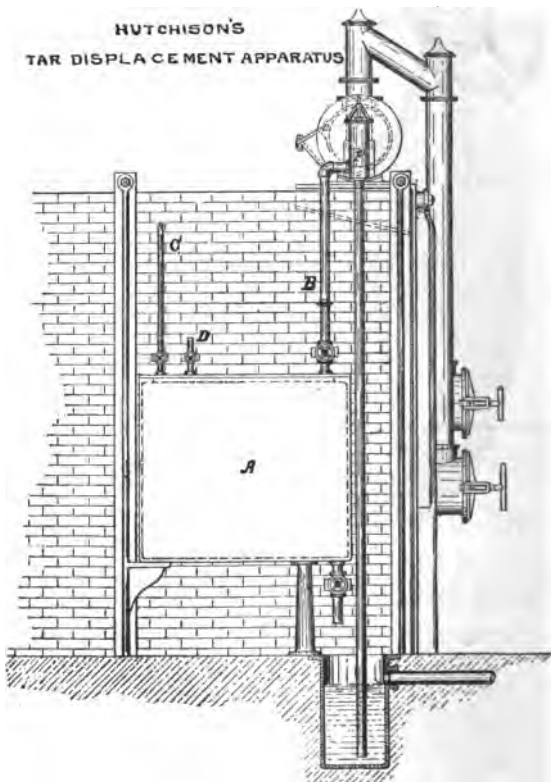
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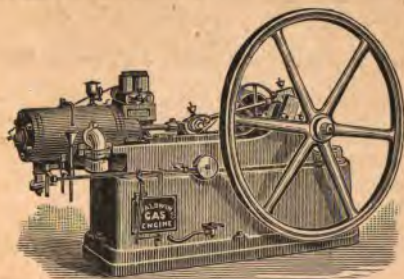
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